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| **Joint Video Experts Team (JVET)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11**  12th Meeting: Macao, CN, 3–12 Oct. 2018 | Document: JVET-L\_Notes\_dD |

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| *Title:* | **Meeting Report of the 12th meeting of the Joint Video Experts Team (JVET), Macao, CN, 3–12 October 2018** | | |
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| *Purpose:* | Report | | |
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| *Source:* | Chairs of JVET | | |

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# Summary

The Joint Video Experts Team (JVET) of ITU-T WP3/16 and ISO/IEC JTC 1/ SC 29/ WG 11 held its twelfth meeting during 3–12 October 2018 at the Venetian Macao Resort Hotel (Estrada da Baía de N. Senhora da Esperança, s/n Taipa, Macao S.A.R., China). The JVET meeting was held under the chairmanship of Dr Gary Sullivan (Microsoft/USA) and Dr Jens-Rainer Ohm (RWTH Aachen/Germany). For rapid access to particular topics in this report, a subject categorization is found (with hyperlinks) in section 2.13 of this document. It is further noted that the unabbreviated name of JVET was formerly known as “Joint Video *Exploration* Team”, but the parent bodies had modified it when entering the phase of formal development of a new standard by the previous meeting. The name Versatile Video Coding (VVC) was chosen as the informal nickname for the new standard.

The JVET meeting began at approximately 0900 hours on Wednesday 3 October 2018. Meeting sessions were held on all days (including weekend days) until the meeting was closed at approximately 1330 hours on Friday 12 October 2018. Approximately 286 people attended the JVET meeting, and approximately XXX input documents and 16 AHG reports were discussed. The meeting took place in a collocated fashion with a meeting of WG11 – one of the two parent bodies of the JVET. The subject matter of the JVET meeting activities consisted of developing video coding technology with a compression capability that significantly exceeds that of the current HEVC standard, or otherwise gives better support regarding the requirements of future application domains of video coding. As a primary goal, the JVET meeting reviewed the work that was performed in the interim period since the eleventh JVET meeting in producing a second draft of the VVC standard and the second version of the associated VVC test model (VTM). Further important goals were reviewing the results of 15 Core Experiments (CE), reviewing other technical input on novel aspects of video coding technology, and producing the next versions of the VVC draft text and VTM, and plan next steps for further investigation of candidate technology towards the formal standard development.

The JVET produced 21 output documents from the meeting:

* JVET-L1001 Versatile Video Coding specification text (Draft 3)
* JVET-L1002 Algorithm description for Versatile Video Coding and Test Model 3 (VTM 3)
* JVET-L1004 Algorithm descriptions of projection format conversion and video quality metrics in 360Lib (Version 8)
* JVET-L1005 and JVET-L1006 Methodology and reporting template for coding tool testing and for neural network tool testing
* JVET-L1010, JVET-L1011, and JVET-L1012 JVET common test conditions and software reference configurations for SDR, HDR/WCG, and 360° video
* JVET-L1021 through JVET-L1033, Description of Core Experiments 1 through 13

For the organization and planning of its future work, the JVET established 17 “ad hoc groups” (AHGs) to progress the work on particular subject areas. At this meeting, 13 Core Experiments (CE) were defined. The next four JVET meetings were planned for 9–18 January 2019 under WG11 auspices in Marrakech, MA, during 19–27 March 2019 under ITU-T SG16 auspices in Geneva, CH, during 3–12 July 2019 under WG 11 auspices in Gothenburg, SE, and during 1–9 October 2019 under ITU-T SG16 auspices in Geneva, CH.

The document distribution site <http://phenix.it-sudparis.eu/jvet/> was used for distribution of all documents.

The reflector to be used for discussions by the JVET and all its AHGs is the JVET reflector:  
[jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de) hosted at RWTH Aachen University. For subscription to this list, see  
<https://mailman.rwth-aachen.de/mailman/listinfo/jvet>.

# Administrative topics

## Organization

The ITU-T/ISO/IEC Joint Video Experts Team (JVET) is a group of video coding experts from the ITU-T Study Group 16 Visual Coding Experts Group (VCEG) and the ISO/IEC JTC 1/SC 29/WG 11 Moving Picture Experts Group (MPEG). The parent bodies of the JVET are ITU-T WP3/16 and ISO/IEC JTC 1/SC 29/WG 11.

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It is further noted that the unabbreviated name of JVET was formerly known as “Joint Video *Exploration* Team”, but the parent bodies had modified it when entering the phase of formal development of a new standard by the previous meeting. The name Versatile Video Coding (VVC) was chosen as the informal nickname for the new standard.

## Meeting logistics

Information regarding logistics arrangements for the meeting had been provided via the email reflector [jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de) and at <http://wftp3.itu.int/av-arch/jvet-site/2018_10_L_Macao/>.

## Primary goals

As a primary goal, the JVET meeting reviewed the work that was performed in the interim period since the eleventh JVET meeting in producing a secomd draft of the VVC standard and the second version of the associated VVC test model (VTM). Further important goals were reviewing the results of 15 Core Experiments (CE), reviewing other technical input on novel aspects of video coding technology, and producing the next versions of draft text and VTM, and plan next steps for further investigation of candidate technology towards the formal standard development.

## Documents and document handling considerations

### General

The documents of the JVET meeting are listed in Annex A of this report. The documents can be found at <http://phenix.it-sudparis.eu/jvet/>.

Registration timestamps, initial upload timestamps, and final upload timestamps are listed in Annex A of this report.

The document registration and upload times and dates listed in Annex A and in headings for documents in this report are in Paris/Geneva time. Dates mentioned for purposes of describing events at the meeting (other than as contribution registration and upload times) follow the local time at the meeting facility.

Highlighting of recorded decisions in this report is practised as follows:

* Decisions made by the group that might affect the normative content of a future standard are identified in this report by prefixing the description of the decision with the string “Decision:”.
* Decisions that affect the VTM or BMS software but have no normative effect are marked by the string “Decision (SW):”.
* Decisions that fix a “bug” in the VTM description (an error, oversight, or messiness) or in the software are marked by the string “Decision (BF):”.

This meeting report is based primarily on notes taken by the JVET chairs. The preliminary notes were also circulated publicly by ftp and http during the meeting on a daily basis. It should be understood by the reader that 1) some notes may appear in abbreviated form, 2) summaries of the content of contributions are often based on abstracts provided by contributing proponents without an intent to imply endorsement of the views expressed therein, and 3) the depth of discussion of the content of the various contributions in this report is not uniform. Generally, the report is written to include as much information about the contributions and discussions as is feasible (in the interest of aiding study), although this approach may not result in the most polished output report.

### Late and incomplete document considerations

The formal deadline for registering and uploading non-administrative contributions had been announced as Monday, 24 September 2018. Any documents uploaded after 1159 hours Paris/Geneva time on Tuesday 25 September were considered “officially late”, giving a grace period of 12 hours to accommodate those living in different time zones of the world. The deadline does not apply to AHG reports, CE summaries, and other such reports which can only be produced after the availability of other input documents.

All contribution documents with registration numbers JVET-L0430 and higher were registered after the “officially late” deadline (and therefore were also uploaded late). However, some documents in the “K0430+” range might include break-out activity reports that were generated during the meeting, and are therefore better considered as report documents rather than as late contributions. Also, many cross-check reports were uploaded late.

In many cases, contributions were also revised after the initial version was uploaded. The contribution document archive website retains publicly accessible prior versions in such cases. The timing of late document availability for contributions is generally noted in the section discussing each contribution in this report.

One suggestion to assist with the issue of late submissions was to require the submitters of late contributions and late revisions to describe the characteristics of the late or revised (or missing) material at the beginning of discussion of the contribution. This was agreed to be a helpful approach to be followed at the meeting.

The following technical design proposal contributions were registered and/or uploaded late:

* JVET-L0066 (a proposal on reduction of reference sample lines), uploaded 10-04.
* ….

It may be observed that some of the above-listed contributions were submissions made in response to issues that arose in discussions during the meeting or from the study of other contributions, and thus could not have been submitted by the ordinary deadline. For example, some of them were proposing combinations or simplifications of other proposals.

The following other document not proposing normative technical content, but with some need for consideration, were registered and/or uploaded late:

* JVET-L0XXX (a document on …), uploaded XX-XX.
* ….

The following cross-verification reports were registered before the deadline and uploaded late: JVET-L0XXX [uploaded XX-XX], … . Cross-verification reports that were both registered late and uploaded late (those with numbers higher than JVET-L0XXX) are not specifically identified here, in the interest of brevity. Initial upload times for each document are recorded in Annex A of this report.

The following contribution registrations were later cancelled, withdrawn, never provided, were cross-checks of a withdrawn contribution, or were registered in error: , , , , , , , , , , , , , , , , , , 4, , , , , , , , , and .

“Placeholder” contribution documents that were basically empty of content, with perhaps only a brief abstract and some expression of an intent to provide a more complete submission as a revision, had been agreed to be considered unacceptable and rejected in the document management system. There were no initial uploads of contribution documents that were rejected as “placeholders” at the current meeting.

As a general policy, missing documents were not to be presented, and late documents (and substantial revisions) could only be presented when there was a consensus to consider them and there was sufficient time available for their review. Again, an exception is applied for AHG reports, CE summaries, and other such reports which can only be produced after the availability of other input documents. There were no objections raised by the group regarding presentation of late contributions, although there was some expression of annoyance and remarks on the difficulty of dealing with late contributions and late revisions.

It was remarked that documents that are substantially revised after the initial upload can also be a problem, as this becomes confusing, interferes with study, and puts an extra burden on synchronization of the discussion. This can especially be a problem in cases where the initial upload is clearly incomplete, and in cases where it is difficult to figure out what parts were changed in a revision. For document contributions, revision marking is very helpful to indicate what has been changed. Also, the “comments” field on the web site can be used to indicate what is different in a revision although participants tend to seldom notice what is recorded there.

A few contributions may have had some problems relating to IPR declarations in the initial uploaded versions (missing declarations, declarations saying they were from the wrong companies, etc.). These issues were corrected by later uploaded versions in a reasonably timely fashion in all cases (to the extent of the awareness of the responsible coordinators).

Some other errors were noticed in other initial document uploads (wrong document numbers or meeting dates or meeting locations in headers, etc.) which were generally sorted out in a reasonably timely fashion. The document web site contains an archive of each upload.

### Outputs of the preceding meeting

All output documents of the previous meeting, particularly the meeting report JVET-K1000, the Versatile Video Coding specification text (Draft 2) JVET-K1001, the Algorithm description for Versatile Video Coding and Test Model 2 (VTM 2) JVET-K1002, the Guidelines for VVC Software Development JVET-K1003, the Algorithm descriptions of projection format conversion and video quality metrics in 360Lib Version 7 JVET-K1004, the Methodology and reporting template for tool testing JVET-K1005, the JVET common test conditions and software reference configurations for SDR, HDR/WCG, and 360° video (JVET-K1010, JVET-K1011, and JVET-K1012), and the Description of Core Experiments 1 through 15 (JVET-K1021 through JVET-K1035), had been completed and were approved. The software implementations of VTM (versions 2.0 and 2.1), BMS (versions 2.0 and 2.1), and the 360Lib software implementation (version 7.0) were also approved. Furthermore, one last missing output document of the 10th meeting, the Report of results from the Call for Proposals on Video Compression with Capability beyond HEVC JVET-J1003, had been finally delivered and was approved.

The group had initially been asked to review the meeting report of the previous meeting for finalization. The meeting report was later approved after a minor editorial revision (replacing some tables that had been included as images with proper text, and minor wording changes).

The available output documents of the previous meeting and the software had been made available in a reasonably timely fashion.

## Attendance

The list of participants in the JVET meeting can be found in Annex B of this report.

The meeting was open to those qualified to participate either in ITU-T WP3/16 or ISO/IEC JTC 1/‌SC 29/‌WG 11 (including experts who had been personally invited as permitted by ITU-T or ISO/IEC policies).

Participants had been reminded of the need to be properly qualified to attend. Those seeking further information regarding qualifications to attend future meetings may contact the responsible coordinators.

## Agenda

The agenda for the meeting was as follows:

* Opening remarks and review of meeting logistics and communication practices
* IPR policy reminder and declarations
* Contribution document allocation
* Review of results of the previous meeting
* Reports of *ad hoc* group (AHG) activities
* Reports of core experiments planned at the previous meeting
* Consideration of contributions and communications on project guidance
* Consideration of video coding technology contributions
* Consideration of information contributions
* Coordination activities
* Approval of output documents and associated editing periods
* Future planning: Determination of next steps, discussion of working methods, communication practices, establishment of coordinated experiments, establishment of AHGs, meeting planning, other planning issues
* Other business as appropriate for consideration

## IPR policy reminder

Participants were reminded of the IPR policy established by the parent organizations of the JVET and were referred to the parent body websites for further information. The IPR policy was summarized for the participants.

The ITU-T/ITU-R/ISO/IEC common patent policy shall apply. Participants were particularly reminded that contributions proposing normative technical content shall contain a non-binding informal notice of whether the submitter may have patent rights that would be necessary for implementation of the resulting standard. The notice shall indicate the category of anticipated licensing terms according to the ITU-T/ITU-R/ISO/IEC patent statement and licensing declaration form.

This obligation is supplemental to, and does not replace, any existing obligations of parties to submit formal IPR declarations to ITU-T/ITU-R/ISO/IEC.

Participants were also reminded of the need to formally report patent rights to the top-level parent bodies (using the common reporting form found on the database listed below) and to make verbal and/or document IPR reports within the JVET necessary in the event that they are aware of unreported patents that are essential to implementation of a standard or of a draft standard under development.

Some relevant links for organizational and IPR policy information are provided below:

* <http://www.itu.int/ITU-T/ipr/index.html> (common patent policy for ITU-T, ITU-R, ISO, and IEC, and guidelines and forms for formal reporting to the parent bodies)
* <http://ftp3.itu.int/av-arch/jvet-site> (JVET contribution templates)
* <http://www.itu.int/ITU-T/dbase/patent/index.html> (ITU-T IPR database)
* <http://www.itscj.ipsj.or.jp/sc29/29w7proc.htm> (JTC 1/‌SC 29 Procedures)

It is noted that the ITU TSB director’s AHG on IPR had issued a clarification of the IPR reporting process for ITU-T standards, as follows, per SG 16 TD 327 (GEN/16):

“TSB has reported to the TSB Director’s IPR Ad Hoc Group that they are receiving Patent Statement and Licensing Declaration forms regarding technology submitted in Contributions that may not yet be incorporated in a draft new or revised Recommendation. The IPR Ad Hoc Group observes that, while disclosure of patent information is strongly encouraged as early as possible, the premature submission of Patent Statement and Licensing Declaration forms is not an appropriate tool for such purpose.

In cases where a contributor wishes to disclose patents related to technology in Contributions, this can be done in the Contributions themselves, or informed verbally or otherwise in written form to the technical group (e.g. a Rapporteur’s group), disclosure which should then be duly noted in the meeting report for future reference and record keeping.

It should be noted that the TSB may not be able to meaningfully classify Patent Statement and Licensing Declaration forms for technology in Contributions, since sometimes there are no means to identify the exact work item to which the disclosure applies, or there is no way to ascertain whether the proposal in a Contribution would be adopted into a draft Recommendation.

Therefore, patent holders should submit the Patent Statement and Licensing Declaration form at the time the patent holder believes that the patent is essential to the implementation of a draft or approved Recommendation.”

The responsible coordinators invited participants to make any necessary verbal reports of previously-unreported IPR in technology that might be considered as prospective candidate for inclusion in future standards, and opened the floor for such reports: No such verbal reports were made.

## Software copyright disclaimer header reminder

It was noted that the VTM software implementation package uses the same software copyright license header as the HEVC reference software, where the latter had been agreed at the 5th meeting of the JCT-VC and approved by both parent bodies at their collocated meetings at that time. This license header language is based on the BSD license with a preceding sentence declaring that other contributor or third party rights, including patent rights, are not granted by the license, as recorded in N10791 of the 89th meeting of ISO/IEC JTC 1/‌SC 29/‌WG 11. Both ITU and ISO/IEC will be identified in the <OWNER> and <ORGANIZATION> tags in the header. This software is used in the process of designing the VTM software, and for evaluating proposals for technology to be potentially included in the design. This software or parts thereof might be published by ITU-T and ISO/IEC as an example implementation of a future video coding standard and for use as the basis of products to promote adoption of such technology.

Different copyright statements shall not be committed to the committee software repository (in the absence of subsequent review and approval of any such actions). As noted previously, it must be further understood that any initially-adopted such copyright header statement language could further change in response to new information and guidance on the subject in the future.

These considerations apply to the 360Lib video conversion software and and HDRtools as well.

## Communication practices

The documents for the meeting can be found at <http://phenix.it-sudparis.eu/jvet/>.

It was reminded to send a notice to the chairs in cases of changes to document titles, authors etc.

JVET email lists are managed through the site <https://mailman.rwth-aachen.de/mailman/options/jvet>, and to send email to the reflector, the email address is [jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de). Only members of the reflector can send email to the list. However, membership of the reflector is not limited to qualified JVET participants.

It was emphasized that reflector subscriptions and email sent to the reflector must use real names when subscribing and sending messages and subscribers must respond to inquiries regarding the nature of their interest in the work. The current number of subscribers was 928.

For distribution of test sequences, a password-protected ftp site had been set up at RWTH Aachen University, with a mirror site at FhG-HHI. Accredited members of JVET may contact the responsible JVET coordinators to obtain the password information (but the site is not open for use by others).

## Terminology

Some terminology used in this report is explained below:

* **ACT**: Adaptive colour transform.
* **AI**: All-intra.
* **AIF**: Adaptive interpolation filtering.
* **ALF**: Adaptive loop filter.
* **AMP**: Asymmetric motion partitioning – a motion prediction partitioning for which the sub-regions of a region are not equal in size (in HEVC, being N/2x2N and 3N/2x2N or 2NxN/2 and 2Nx3N/2 with 2N equal to 16 or 32 for the luma component).
* **AMVP**: Adaptive motion vector prediction.
* **AMT or MTS**: Adaptive multi-core transform, or multiple transform set.
* **AMVR**: (Locally) adaptive motion vector resolution.
* **APS**: Active parameter sets.
* **ARC**: Adaptive resolution conversion (synonymous with DRC, and a form of RPR).
* **ARSS**: Adaptive reference sample smoothing.
* **ATMVP or “**subblock-based temporal merging candidates**”** : Alternative temporal motion vector prediction.
* **AU**: Access unit.
* **AUD**: Access unit delimiter.
* **AVC**: Advanced video coding – the video coding standard formally published as ITU-T Recommendation H.264 and ISO/IEC 14496-10.
* **BA**: Block adaptive.
* **BC**: See CPR or IBC.
* **BD**: Bjøntegaard-delta – a method for measuring percentage bit rate savings at equal PSNR or decibels of PSNR benefit at equal bit rate (e.g., as described in document VCEG-M33 of April 2001).
* **BIO**: Bi-directional optical flow.
* **BL**: Base layer.
* **BMS**: Bench-mark set, a compilation of coding tools on top of VTM, which provide somewhat better compression performance, but are not deemed mature for standardzation.
* **BoG**: Break-out group.
* **BR**: Bit rate.
* **BV**: Block vector (used for intra BC prediction).
* **CABAC**: Context-adaptive binary arithmetic coding.
* **CBF**: Coded block flag(s).
* **CC**: May refer to context-coded, common (test) conditions, or cross-component.
* **CCLM**: Cross-component linear model.
* **CCP**: Cross-component prediction.
* **CG**: Coefficient group.
* **CGS**: Colour gamut scalability (historically, coarse-grained scalability).
* **CL-RAS**: Cross-layer random-access skip.
* **CPMVP**: Control-point motion vector prediction (used in affine motion model).
* **CPR**: Current-picture referencing, also known as IBC – a technique by which sample values are predicted from other samples in the same picture by means of a displacement vector called a block vector, in a manner conceptually similar to motion-compensated prediction.
* **CTC**: Common test conditions.
* **CVS**: Coded video sequence.
* **DCT**: Discrete cosine transform (sometimes used loosely to refer to other transforms with conceptually similar characteristics).
* **DCTIF**: DCT-derived interpolation filter.
* **DF**: Deblocking filter.
* **DMVR**: Decoder-side motion vector refinement.
* **DRC**: Dynamic resolution conversion (synonymous with ARC, and a form of RPR).
* **DT**: Decoding time.
* **ECS**: Entropy coding synchronization (typically synonymous with WPP).
* **EE**: Exploration Experiment – a coordinated experiment conducted toward assessment of coding technology.
* **EMT**: Explicit multiple-core transform.
* **EOTF**: Electro-optical transfer function – a function that converts a representation value to a quantity of output light (e.g., light emitted by a display.
* **EPB**: Emulation prevention byte (as in the emulation\_prevention\_byte syntax element).
* **ECV**: Extended Colour Volume (up to WCG).
* **EL**: Enhancement layer.
* **ET**: Encoding time.
* **FRUC**: Frame rate up conversion (pattern matched motion vector derivation).
* **HDR**: High dynamic range.
* **HEVC**: High Efficiency Video Coding – the video coding standard developed and extended by the JCT-VC, formalized by ITU-T as Rec. ITU-T H.265 and by ISO/IEC as ISO/IEC 23008-2.
* **HLS**: High-level syntax.
* **HM**: HEVC Test Model – a video coding design containing selected coding tools that constitutes our draft standard design – now also used especially in reference to the (non-normative) encoder algorithms (see WD and TM).
* **HyGT**: Hyper-cube Givens transform (a type of NSST).
* **IBC** (also **Intra BC**): Intra block copy, also known as CPR – a technique by which sample values are predicted from other samples in the same picture by means of a displacement vector called a block vector, in a manner conceptually similar to motion-compensated prediction.
* **IBDI**: Internal bit-depth increase – a technique by which lower bit-depth (8 bits per sample) source video is encoded using higher bit-depth signal processing, ordinarily including higher bit-depth reference picture storage (ordinarily 12 bits per sample).
* **IBF**: Intra boundary filtering.
* **ILP**: Inter-layer prediction (in scalable coding).
* **IPCM**: Intra pulse-code modulation (similar in spirit to IPCM in AVC and HEVC).
* **JEM**: Joint exploration model – the software codebase for future video coding exploration.
* **JM**: Joint model – the primary software codebase that has been developed for the AVC standard.
* **JSVM**: Joint scalable video model – another software codebase that has been developed for the AVC standard, which includes support for scalable video coding extensions.
* **KLT**: Karhunen-Loève transform.
* **LB** or **LDB**: Low-delay B – the variant of the LD conditions that uses B pictures.
* **LD**: Low delay – one of two sets of coding conditions designed to enable interactive real-time communication, with less emphasis on ease of random access (contrast with RA). Typically refers to LB, although also applies to LP.
* **LIC**: Local illumination compensation.
* **LM**: Linear model.
* **LP** or **LDP**: Low-delay P – the variant of the LD conditions that uses P frames.
* **LUT**: Look-up table.
* **LTRP**: Long-term reference pictures.
* **MC**: Motion compensation.
* **MCP**: Motion compensated prediction.
* **MDNSST**: Mode dependent non-separable secondary transform.
* **MMLM**: Multi-model (cross component) linear mode.
* **MPEG**: Moving picture experts group (WG 11, the parent body working group in ISO/IEC JTC 1/‌SC 29, one of the two parent bodies of the JVET).
* **MPM**: Most probable mode (in intra prediction).
* **MV**: Motion vector.
* **MVD**: Motion vector difference.
* **NAL**: Network abstraction layer (as in AVC and HEVC).
* **NSQT**: Non-square quadtree.
* **NSST**: Non-separable secondary transform.
* **NUH**: NAL unit header.
* **NUT**: NAL unit type (as in AVC and HEVC).
* **OBMC**: Overlapped block motion compensation (e.g., as in H.263 Annex F).
* **OETF**: Opto-electronic transfer function – a function that converts to input light (e.g., light input to a camera) to a representation value.
* **OOTF**: Optical-to-optical transfer function – a function that converts input light (e.g. l,ight input to a camera) to output light (e.g., light emitted by a display).
* **PDPC**: Position dependent (intra) prediction combination.
* **PMMVD**: Pattern-matched motion vector derivation.
* **POC**: Picture order count.
* **PoR**: Plan of record.
* **PPS**: Picture parameter set (as in AVC and HEVC).
* **QM**: Quantization matrix (as in AVC and HEVC).
* **QP**: Quantization parameter (as in AVC and HEVC, sometimes confused with quantization step size).
* **QT**: Quadtree.
* **BT**: Binary tree.
* **TT**: Ternary tree.
* **RA**: Random access – a set of coding conditions designed to enable relatively-frequent random access points in the coded video data, with less emphasis on minimization of delay (contrast with LD).
* **RADL**: Random-access decodable leading.
* **RASL**: Random-access skipped leading.
* **R-D**: Rate-distortion.
* **RDO**: Rate-distortion optimization.
* **RDOQ**: Rate-distortion optimized quantization.
* **ROT**: Rotation operation for low-frequency transform coefficients.
* **RPLM**: Reference picture list modification.
* **RPR**: Reference picture resampling (e.g., as in H.263 Annex P), a special case of which is also known as ARC or DRC.
* **RPS**: Reference picture set.
* **RQT**: Residual quadtree.
* **RRU**: Reduced-resolution update (e.g. as in H.263 Annex Q).
* **RVM**: Rate variation measure.
* **SAO**: Sample-adaptive offset.
* **SD**: Slice data; alternatively, standard-definition.
* **SDT**: Signal dependent transform.
* **SEI**: Supplemental enhancement information (as in AVC and HEVC).
* **SH**: Slice header.
* **SHM**: Scalable HM.
* **SHVC**: Scalable high efficiency video coding.
* **SIMD**: Single instruction, multiple data.
* **SPS**: Sequence parameter set (as in AVC and HEVC).
* **STMVP**: Spatial-temporal motion vector prediction.
* **TBA/TBD/TBP**: To be announced/determined/presented.
* **TGM**: Text and graphics with motion – a category of content that primarily contains rendered text and graphics with motion, mixed with a relatively small amount of camera-captured content.
* **UCBDS**: Unrestricted center-biased diamond search.
* **UWP**: Unequal weight prediction.
* **VCEG**: Visual coding experts group (ITU-T Q.6/16, the relevant rapporteur group in ITU-T WP3/16, which is one of the two parent bodies of the JVET).
* **VPS**: Video parameter set – a parameter set that describes the overall characteristics of a coded video sequence – conceptually sitting above the SPS in the syntax hierarchy.
* **VTM**: VVC Test Model.
* **VVC**: Versatile Video Coding, the standardization project developed by JVET.
* **WCG**: Wide colour gamut.
* **WG**: Working group, a group of technical experts (usually used to refer to WG 11, a.k.a. MPEG).
* **WPP**: Wavefront parallel processing (usually synonymous with ECS).
* Block and unit names in HEVC:
  + **CTB**: Coding tree block (luma or chroma) – unless the format is monochrome, there are three CTBs per CTU.
  + **CTU**: Coding tree unit (containing both luma and chroma, synonymous with LCU), with a size of 16x16, 32x32, or 64x64 for the luma component.
  + **CB**: Coding block (luma or chroma), a luma or chroma block in a CU.
  + **CU**: Coding unit (containing both luma and chroma), the level at which the prediction mode, such as intra versus inter, is determined in HEVC, with a size of 2Nx2N for 2N equal to 8, 16, 32, or 64 for luma.
  + **PB**: Prediction block (luma or chroma), a luma or chroma block of a PU, the level at which the prediction information is conveyed or the level at which the prediction process is performed in HEVC.
  + **PU**: Prediction unit (containing both luma and chroma), the level of the prediction control syntax within a CU, with eight shape possibilities in HEVC:
    - **2Nx2N**: Having the full width and height of the CU.
    - **2NxN (or Nx2N)**: Having two areas that each have the full width and half the height of the CU (or having two areas that each have half the width and the full height of the CU).
    - **NxN**: Having four areas that each have half the width and half the height of the CU, with N equal to 4, 8, 16, or 32 for intra-predicted luma and N equal to 8, 16, or 32 for inter-predicted luma – a case only used when 2N×2N is the minimum CU size.
    - **N/2x2N** paired with **3N/2x2N** or **2NxN/2** paired with **2Nx3N/2**: Having two areas that are different in size – cases referred to as AMP, with 2N equal to 16 or 32 for the luma component.
  + **TB**: Transform block (luma or chroma), a luma or chroma block of a TU, with a size of 4x4, 8x8, 16x16, or 32x32.
  + **TU**: Transform unit (containing both luma and chroma), the level of the residual transform (or transform skip or palette coding) segmentation within a CU (which, when using inter prediction in HEVC, may sometimes span across multiple PU regions).
* Block and unit names in JEM (Note: Need to put VVC terminology here):
  + **CTB**: Coding tree block (luma or chroma) – there are three CTBs per CTU in P/B slice, and one CTB per luma CTU and two CTBs per chroma CTU in I slice.
  + **CTU**: Coding tree unit (synonymous with LCU, containing both luma and chroma in P/B slice, containing only luma or chroma in I slice), with a size of 16x16, 32x32, 64x64, or 128x128 for the luma component.
  + **CB**: Coding block, a luma or chroma block in a CU.
  + **CU**: Coding unit (containing both luma and chroma in P/B slice, containing only luma or chroma in I slice), a leaf node of a QTBT. It’s the level at which the prediction process and residual transform are performed in JEM. A CU can be square or rectangle shape.
  + **PB**: Prediction block, a luma or chroma block of a PU.
  + **PU**: Prediction unit, has the same size to a CU.
  + **TB**: Transform block, a luma or chroma block of a TU.
  + **TU**: Transform unit, has the same size to a CU.

## Opening remarks

Remarks during the opening session of the meeting 0900 Wednesday 3 October (chaired by GJS and JRO) were as follows.

* The meeting logistics, agenda, working practices, policies, and document allocation were reviewed.
* The results of the previous meeting were reviewed.
  + A very late output of the April meeting (the CfP evaluation report) had been produced.
  + On placeholders – there were a number of cases where there was some description of a concept but no test results.
    - L0111 (maybe that was OK), L0167, L0174, L0175, L0176, L0177, L0178?, L0186, L0187, L0188, L0189, L0241, L0325, L0408
  + There was a comment about “piecemeal” revisions of documents; properly, a contribution should be complete when its initial version is uploaded. It should not need repeated revisions to finalize its content.
  + The software integration went somewhat slower than expected.
  + There was substantial discussion of the nature and conduct of CEs:
    - There were some cases with differences between CE plan descriptions and what is reported in a CE report.
    - The CE plan descriptions need to be accurate and complete.
    - The CE4 report identifies some cases where there were late modifications.
    - The software needs to match the description.
    - Cross-checkers need stable software.
    - Text needs to be available.
    - The notes of the last meeting said the RoS for ALF was 7x7, but the software and text also had 5x5. (There was some modification of the proposed scheme, removing fixed filters which were always 7x7 from what had been tested, and in the discussion it was suggested that this might have been the cause of some of the confusion.)
    - See section 13.4 for refinement of CE plans, partly revised in the opening discussion.
  + It was asked whether the rate control scheme of JVET-K0390 could also apply to the HM. A further input contribution rate control had also been submitted to the current meeting as JVET-L0241. Coordination with JCT-VC on HM development was encouraged.
* The primary goals of the meeting were to review the results of CEs, identify promising technology directions, and adopt proposed technology into the VVC draft text and VTM.
* Due to the high number of input contributions, parallelization and breakout work were expected to be needed.
* Principles of standards development were discussed.

## Scheduling of discussions

Scheduling: Generally meeting time was scheduled during 0900–2100+ hours, with coffee and lunch breaks as convenient. Ongoing scheduling refinements were announced on the group email reflector as needed. Some particular scheduling notes are shown below, although not necessarily 100% accurate or complete:

* Wed. 3 October, 1st day
  + 0900–1100 Opening plenary (chaired by GJS & JRO)
  + 1115–1320, 1500–1830 AHG reports plenary review (chaired by GJS & JRO)
  + 1830–2030 Plenary HLS concepts JVET-L0110 (chaired by GJS & JRO)
* Thu. 4 October, 2nd day
  + 0900–1130 CE2 (ALF) in Track B
  + 1145‒2100 CE4 (inter prediction) in Track B
* Fri. 5 October, 3rd day
  + 0900‒1000 CE4 in Track B
  + 1000‒1200 CE9 (decoder motion vector derivation) in Track B
  + 1200‒ CE10 Multi-hypothesis and combined prediction in Track B
  + 0900‒?, 1330 (Viewing), 1430‒1200 (review of viewing) 360° BoG (3rd room)
  + 1600‒ HLS in Track B (3rd room)
  + 1600 CE4-related BoG (2nd room)
* Sat. 6 October, 4th day
  + 0900–1400 JCT-VC opening plenary
  + BoG on CE4 related
  + 1530–XXXX CE10 in Track B
  + 0900–1230 Plenary (chaired by GJS & JRO)
  + 1300 360° BoG (4th room)
  + 1400 Track A [add detail] (main room)
  + 1400 CE4-related BoG (2nd room)
  + 1400 Track B High-level syntax (3rd room)
  + 1400 Reconstruction filtering BoG (4th room)
  + 1630 CABAC BoG (focus on throughput & implementation aspects, 3rd room)
  + 1800 Transform BoG (main room)
  + 1800–2000 CE9-related Decoder motion vector derivation BoG (4th room)
  + 1800 Deblocking BoG (3rd room)
* Mon. 8 October, 6th day
  + 0900–1230 WG 11 parent-body opening plenary
  + 1400 Track A planning and proceeding
  + 1400–1745 Track B planning and BoG review
  + 1800–2100 Track B high-level syntax
* Tue. 9 October, 7th day
  + 0900–1100 VCEG parent-body opening plenary
  + 1100–1330 Track B finalization of CE4-related
  + 1400–1500 VCEG & MPEG joint meeting (not on JVET topics)
  + 1500-1800 JCT-VC session
* Wed. 10 October, 8th day
  + 0800-0900 VCEG parent-body meeting
  + 0900–1100 WG 11 parent-body mid-week plenary
  + 1115 Track A
  + 1115 Track B CE4 and CE10 related further discussions
  + 1400 Plenary
  + 1600 Track A
  + 1600 Track B HLS
  + 1830 Social Event
* Thu. 11 October, 9th day
* Fri. 12 October, 10th day
  + 1400–2000 WG 11 parent-body closing plenary

## Contribution topic overview

The approximate subject categories and quantity of contributions per category for the meeting were summarized as follows (note that document count was not kept up to date since d3):

* AHG reports (16) (section 3) (Plenary)
* Project development (2) (section 4) (Plenary)
* Test material (1) (section 4.3) (Plenary)
* Core Experiments (xx) (section 6) with subtopics [check merge of d6\_g2 notes]
  + CE1: Partitioning (6) (section 6.1) (Track A)
  + CE2: Loop filters (7) (section 6.2) (Track B) – Text to be checked
  + CE3: Intra prediction and mode coding (36) (section 6.3) (Track A)
  + CE4: Inter prediction and motion vector coding (51) (section 6.4) (Track B) – Text to be checked
  + CE5: Arithmetic coding engine (11) (section 6.5) (Track A)
  + CE6: Transforms and transform signalling (19) (section 6.6) (Track A)
  + CE7: Quantization and coefficient coding (7) (section 6.7) (Track A)
  + CE8: Current picture referencing (6) (section 6.8) (Track A)
  + CE9: Decoder motion vector derivation (15) (section 6.9) (Track B) [Done]
  + CE10: Combined and multi-hypothesis prediction (18) (section 6.10) (Track B)
  + CE11: Deblocking (20) (section 6.11) (Track A)
  + CE12: Mapping functions (5) (section 6.12) (Track A)
  + CE13: Coding tools for 360° video (21) (section 6.13) (BoG)
  + CE14: Post reconstruction filtering (4) (section 6.14) (Track A)
  + CE15: Palette mode (3) (section 6.15) (Track A)
* Non-CE technology proposals (xx) (section 7) with subtopics
  + CE1 related – Partitioning (26) (section 7.1) (Track A)
  + CE2 related – Adaptive loop filter (4) (section 7.2) (Track B) [Done]
  + CE3 related – Intra prediction and mode coding (39) (section 7.3) (Track A)
  + CE4 related – Inter prediction and motion vector coding (98) (section 7.4) (Track B) BoG L0691
  + CE5 related – Arithmetic coding engine (5) (section 7.5) (Track A)
  + CE6 related – Transforms and transform signalling (24) (section 7.6) (Track A)
  + CE7 related – Quantization and coefficient coding (20) (section 7.7) (Track A)
  + CE8 related – Current picture referencing (7) (section 7.8) (Track A)
  + CE9 related – Decoder side motion vector derivation (17) (section 7.9) (Track B) – BoG L0693 (X. Xiu) – Done
  + CE10 related – Combined and multi-hypothesis prediction (2) (section 7.10) (Track B) [Done]
  + CE11 related – Deblocking (10) (section 7.11) (Track A)
  + CE12 related – Mapping functions (2) (section 7.12) (Track A)
  + CE13 related – Coding tools for 360° content (4) (section 7.13) (BoG)
  + CE14 related – Post reconstruction filtering (6) (section 7.14) (Track A)
  + CE15 related – Palette mode (10) (section 7.15) (Track A)
  + NN technology related (3) (section 7.14) (Track A)
  + Screen content tools (2) (section 7.17) (Track A)
  + HL syntax (30) (section 7.18) (Track B)
  + PCM (2) (section 7.19) (Track A)
  + QP control (4) (section 7.20)
* Complexity analysis and reduction (0) (section 8) (Track A)
* Encoder optimization (3) (section 9) (Track A)
* Metrics and evaluation criteria (2) (section 10) (Track A)
* Withdrawn (25) (section 11)
* Joint meetings, plenary discussions, BoG reports, Summary of actions (section 12)
* Project planning (section 13)
* Establishment of AHGs (section 14)
* Output documents (section 15)
* Future meeting plans and concluding remarks (section 16)

Track A was generally chaired by JRO, and Track B by GJS.

# AHG reports (16)

These reports were discussed Wednesday 3 October 1120–1320 and 1500-1830 (chaired by GJS and JRO).

[JVET-L0001](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4251) JVET AHG report: Project management (AHG1) [J.-R. Ohm, G. J. Sullivan]

This document reports on the work of the JVET ad hoc group on Project Management, including an overall status report on the VVC standardization project and the progress made during the interim period since the preceding meeting.

In the interim period since the 11th JVET meeting, work towards finalizing the following (23) documents had been performed:

* JVET-K1001 Versatile Video Coding specification text (Draft 2)
* JVET-K1002 Algorithm description for Versatile Video Coding and Test Model 2 (VTM 2)
* JVET-K1003 Guidelines for VVC reference software development
* JVET-K1004 Algorithm descriptions of projection format conversion and video quality metrics in 360Lib Version 7
* JVET-K1005 Methodology and reporting template for tool testing
* JVET-K1010, JVET-K1011, and JVET-K1012 JVET common test conditions and software reference configurations for SDR, HDR/WCG, and 360° video
* JVET-K1021 through JVET-K1035, Description of Core Experiments 1 through 15

Furthermore, one last missing output document of the 10th meeting of April 2018, the Report of Results from the Call for Proposals on Video Compression with Capability beyond HEVC JVET-J1003, had been finally delivered.

The work of the JVET overall had proceeded well in the interim period with a very large number of input documents submitted to the current meeting. Intense discussion had been carried out on the group email reflector, and most output documents from the preceding meeting had been produced.

Except as noted below, output documents from the preceding meeting had been made available at the "Phenix" site (<http://phenix.it-sudparis.eu/jvet/>) or the ITU-based JCT-VC site (<http://wftp3.itu.int/av-arch/jvet-site/2018_07_K_Ljubljana/>), particularly including the following:

* The meeting report (JVET-K1000) [Posted 2018-10-02]
* Versatile Video Coding (Draft 2) (JVET-K1001) [Posted 2018-07-27, last update 2018-10-01]
* Algorithm description for Versatile Video Coding and Test Model 2 (VTM 2) (JVET-K1002) [Posted 2018-08-10, last update 2018-10-02]
* Guidelines for VVC reference software development (JVET-K1003) [Posted 2018-07-24]
* Algorithm descriptions of projection format conversion and video quality metrics in 360Lib Version 7 (JVET-K1004) [Posted 2018-08-29]
* Methodology and reporting template for tool testing (JVET-K1005) [Posted 2018-07-28, last update 2018-09-26]
* JVET common test conditions and software reference configurations (JVET-K1010) [Posted 2018-08-03, last update 2018-09-17]
* JVET common test conditions and evaluation procedures for HDR/WCG video (JVET-K1011) [Posted 2018-08-22]
* JVET common test conditions and evaluation procedures for 360° video (JVET-K1012) [Posted 2018-07-25]
* Description of CE 1..15 (JVET-K1021..35) [all posted 2018-07-18, last updates until 2018-09-27]

The sixteen *ad hoc* groups had made progress, and reports from those activities had been submitted.

Software integration of VTM and BMS was finalized approximately according to the plan.

Various problem reports relating to asserted bugs in the software, draft specification text, and reference encoder description had been submitted to an informal "bug tracking" system. That system is not intended as a replacement of our ordinary contribution submission process. However, the bug tracking system was considered to have been helpful to the software coordinators and text editors. The bug tracker reports had been automatically forwarded to the group email reflector, where the issues were discussed – and this is reported to have been helpful.

The software distribution was migrated to GitLab as planned. The bug tacking system for software aspects was not integrated with GitLab for the time being.

More than 500 input contributions to the current meeting (not counting the AHG reports) had been registered for consideration at the meeting. Most of these relate to Core Experiments.

A preliminary basis for the document subject allocation and meeting notes for the 12th meeting had been made publicly available on the ITU-hosted ftp site.

[JVET-L0002](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4252) JVET AHG report: Draft text and test model algorithm description editing (AHG2) [B. Bross, J. Chen, J. Boyce, S. Kim, S. Liu, Y. Ye]

This document reports the work of the JVET ad hoc group on draft text and test model algorithm description editing (AHG2) between the 11th meeting in Ljubljana, SI (10–18 July 2018) and the 12th meeting in Macao, CN (3–12 October 2018).

The first draft of Versatile Video Coding (VVC D1) includes a quadtree with nested multi-type tree using binary and ternary splits coding block structure as the initial new coding feature of VVC. At the 11th JVET meeting, it was decided to include more coding features for intra picture-prediction, inter-picture prediction, transform coefficient coding, transform, adaptive loop filtering and a starting basis for high-level syntax in the second draft of Versatile Video Coding (VVC D2) and the VVC Test Model 2 (VTM2) encoding. Draft reference software to implement the VVC decoding process and VTM2 encoding method has also been developed.

The normative decoding process for Versatile Video Coding is specified in the VVC draft 2 text specification document. The VVC Test Model 2 (VTM 2) Algorithm and Encoder Description document provides an algorithm description as well as an encoder-side description of the VVC Test Model 2, which serves as a tutorial for the algorithm and encoding model implemented in the VTM2.0 software.

An issue tracker (<https://jvet.hhi.fraunhofer.de/trac/vvc>) was used to facilitate the reporting of errata with the VVC documents.

Seven versions of JVET-K1001 were published by the Editing AHG between the 11th meeting in Ljubljana, SI (10–18 July 2018) and the 12th meeting in Macao, CN (3–12 October 2018).

*JVET-K1001 VVC specification (Draft 2)*

JVET-K1001 has been established based on JVET-J1001 and now contains the following:

* Incorporated JVET-K0230: Separate trees for intra slices (without multi-DMs) with an implicit split to 64x64
* Incorporated JVET-K0556: Prohibit ternary split of something bigger than 64 in width or height (and not send the bit to indicate ternary type at that level)
* Incorporated JVET-K0351 (test c): Keep only the TT restriction (preventing binary split with same orientation in center partition of the ternary split)
* Incorporated JVET-K0554: Implicit splitting at picture boundaries and ensure MinQTSize at boundary splits
* Fixed bug [#65](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/65) typos and unused variables in section 6.4
* Fixed bug [#67](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/67) implicit vertical BT split at picture boundary issue
* Incorporated JVET-K0072: Dependent quantization with fallback switch at the picture level and modified entropy coding supporting dependent quantization including:
  + adapted scaling to non-square transform blocks
  + added binarization process for abs\_remainder
  + specified CoeffMin and CoeffMax with fixed values
  + added 0-th order Exp-Golomb code parsing process
* Incorporated JVET-K0310: Sign data hiding (can only be used when dependent quantization is disabled)
* Incorporated JVET-K0529: Intra prediction using 3MPM on 67 prediction modes (Planar, DC and 65 angular modes)
* Incorporated JVET-K0122: DC prediction without division
* Incorporated JVET-K0500: Wide-angle intra prediction
* Incorporated JVET-K0063: Position-dependent intra prediction combination
* Incorporated JVET-K0190: Cross-component linear model intra prediction
* Incorporated multiple transform selection (MTS) for both intra and inter, each controlled by an SPS flag
* Incorporated transform skip
* Fixed bug [#68](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/68) various typos
* Fixed bug [#71](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/71) various typos
* Fixed bug [#72](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/72) on CCLM
* Incorporated JVET-K0357: adaptive motion vector resolution (AMVR)
* Incorporated JVET-K0565: affine motion compensation (MC) including:
  + JVET-K0052: Affine merge bug fix
  + JVET-K0184: Affine MC (CE4.1.1a 4x4 fixed subblock size)
  + JVET-K0337: Affine MC coding and models (4.1.3a, affine MVP list construction, and 4.1.3b, MV difference coding, and 4.1.3c, 4/6 parameter model, no slice level switch)
  + JVET-K0367/JVET-K0052/JVET-K0103: Restriction of affine merge mode to CU sizes >= 8x8
* Incorporated 1/16 motion compensation (MC) including:
  + 1/16 MV storage
  + 1/16 merge and affine MVs
  + MVDs in AMVR accuracy (1/4-sample, 1-sample, 4-sample) shifted to 1/16
  + Inter MVP candidates rounded to AMVR accuracy (1/4-sample, 1-sample, 4-sample) and shifted to 1/16
  + 1/16 luma and 1/32 chroma interpolation filters
* Incorporated subblock-based temporal merging candidates with 8x8 motion vector storage (JVET-K0346)
* Incorporated JVET-K0371: 4x4 block classification based Adaptive Loop Filter (ALF)
* Fixed bug [#75](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/75) regarding a bottom and right boundary partition issue
* Fixed bug [#90](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/90) typos in copying the control point vectors to temporal notion vectors
* Fixed bug [#86](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/86) in intra reference sample filtering
* Incorporated JVET-K0325: High Level Syntax (HLS) starting point
* Fixed bug [#82](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/82) on zeroing-out high frequency transform coefficients for larger TUs (>32x32)
* Fixed bug [#85](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/85) on MTS index coding

The following items have been discussed within the AHG:

* In HEVC, there is a **restriction on bi-prediction blocks smaller than 8x8 luma samples**. This restriction is currently not in the VVC specification draft and the following input documents have been identified to be related:
  + JVET-L0104 AHG5: Reducing VVC worst-case memory bandwidth by restricting bi-directional 4x4 inter CUs/Sub-blocks
  + JVET-L0122 AHG5: Reduction of worst case memory bandwidth
  + JVET-L0137 CE1-related: Minimum block size restriction
  + JVET-L0396 CE4-related: Affine restrictions for the worst-case bandwidth reduction
  + JVET-L0453 Bugfix for restrictions of bi-prediction for small CUs
  + JVET-L0468 CE4-related: Fixed sub-block size and restriction for ATMVP
* In HEVC, there is a single merge candidate list for all PUs of an 8x8 CU. This was not integrated when the merge candidate list concept was incorporated into the VVC specification draft since there is no partitioning of CUs into PUs. The single merge candidate list was introduced to facilitate **parallel merge estimation** of the PUs inside an 8x8 CU. Related to that, HEVC allows merge estimation regions to enabled parallel merge list derivation for all blocks inside a merge estimation region. This was not incorporated into the VVC specification draft. The syntax is still in VTM software but it was never tested. Furthermore, adaptation to the current VVC design w.r.t the non-square CUs and affine merge candidate list is needed. The following document has been identified to be related:
  + JVET-L0216 Non-CE4: Parallel Merge Estimation for VVC
* In HEVC, the **merge candidate list pruning** is based on partial checks for redundant candidates. This was incorporated into the VVC specification draft. However, the VTM software performs a full pruning of the merge candidate list (meaning each candidate is compared to all other candidates). The following new contributions were noted to be related:
  + JVET-L0093 [add title]
  + JVET-L0214 [add title]
  + JVET-L0282 [add title]
* The decision from the last meeting to increase the maximum QP value from 51 to 63 (JVET-K0251) was not yet incorporated into the VVC specification draft since the current draft does not specify **QP and QP delta coding and derivation**. Due to non-square CUs in VVC, the concept of square quantization groups cannot be carried over from HEVC without modification. The following documents have been identified to be related:
  + JVET-L0362 Quantization parameter signalling
  + JVET-L0428 Delta QP and Chroma QP Offset for Separate Tree
  + JVET-L0553 Fix of Initial QP Signalling
* During the integration of the ALF text, it was noted that the CE description and the meeting notes indicated that the single 7x7 luma shape was adopted. However, the CE software used to generate the results and the VTM implementation uses the adaptive 5x5/7x7 luma filter shape. It was further noted that it does not have big impact on the decoder but it was suggested to discuss the CE process and document CE rules more clearly at this meeting.
* Regarding the above issues discussed within the AHG, it was noted that relevant contributions had been identified for review; see notes on those contributions. Regarding the ALF RoS, this was mostly a process issue. The draft text and software have syntax support for either 5x5 or 7x7 at the slice header level. In general, 5x5 is a special case of 7x7, it was asked to have some experiment data to determine whether the optimization for that case is really necessary (and potentially whether other aspects are also less straightforward than they should be). V. Seregin volunteered to produce some test results. See the notes on CE2 related contributions (the 5x5 special case was removed).
* It was commented that SAO is not in the current draft text, and no benefit had been shown in previous experiments for modifying the SAO as it is in HEVC. It is well agreed that SAO is beneficial.
* Decision: Add SAO as found in HEVC to the draft standard.

*JVET-K1002 VVC Test Model 2 (VTM 2) Algorithm and Encoder Description*

One version of JVET-K1002 was published by the Editing AHG between the 11th meeting in Ljubljana, SI (10–18 July 2018) and the 12th meeting in Macao, CN (3–12 October 2018).

JVET-K1002 has been established based on JVET-J1002 and now contains the following:

* Incorporated JVET-K0230: Separate trees for intra slices (without multi-DMs) with an implicit split to 64x64
* Incorporated JVET-K0556: Prohibit ternary split of something bigger than 64 in width or height (and not send the bit to indicate ternary type at that level)
* Incorporated JVET-K0351 (test c): Keep only the TT restriction (preventing binary split with same orientation in center partition of the ternary split)
* Incorporated JVET-K0554: Implicit splitting at picture boundaries and ensure MinQTSize at boundary splits
* Incorporated JVET-K0063: Position dependent intra prediction combination (PDPC)
* Incorporated JVET-K0190: CCLM only (test 4.1.8)
* Incorporated JVET-K0122: DC prediction bug fix
* Incorporated JVET-K0529: 67 modes with 3MPM and FLC for non-MPM
* Incorporated JVET-K0500: Wide-angle intra prediction for non-square block
* Incorporated MTS (AMT) modification: Multiple transform selection (MTS)
* Incorporated sub-block based TMVP
* Incorporated adaptive motion vector resolution
* Incorporated 8x8 and 1/16 pel motion field storage
* Incorporated affine motion

Description of the following coding features had not yet been added to the test model document:

* 1/16 luma and 1/32 chroma interpolation filters
* JVET-K0072: Dependent quantization with modified entropy coding
* Adaptive loop filter

The AHG recommended to:

* Approve the edited JVET-K1001 and JVET-K1002 documents as JVET outputs,
* Continue to edit the VVC draft and Test Model documents to ensure that all agreed elements of VVC are fully described,
* Compare the VVC documents with the VVC software and resolve any discrepancies that may exist, in collaboration with the software AHG,
* Encourage the use of the issue tracker to report issues with the text of both the VVC specification draft and the algorithm and encoder description,
* Continue to improve the editorial consistency of VVC WD and Test Model documents,

Ensure that, when considering the addition of new feature to VVC, properly drafted text for addition to the VVC Test Model and/or the VVC Working Draft is made available in a timely manner.

[JVET-L0003](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4253) JVET AHG report: Test model software development (AHG3) [F. Bossen, X. Li, K. Sühring]

This report summarizes the activities of the AhG3 on Test model software development that has taken place between the 11th and 12th JVET meetings.

The software development was moved to a GitLab server. Repository location and workflow were announced on the email reflector. BMS 1.1 was checked into a new git repository. BMS versions 2.0, 2.0.1 and 2.1 were developed based on BMS 1.1. VTM versions 2.0, 2.0.1 and 2.1 were extracted from the corresponding BMS version (by removal of macros) and made available in a separate git repository.

A development workflow for core experiments (CEs) was developed and documented. CE coordinators and participants were instructed to follow this workflow.

As decided at the last meeting, development was continued on a GitLab server, allowing participants to register accounts and use a distributed development workflow based on git.

The server is located at:

<https://vcgit.hhi.fraunhofer.de>

The registration and development workflow is documented at:

<https://vcgit.hhi.fraunhofer.de/jvet/VVCSoftware_BMS/wikis/VVC-Software-Development-Workflow>

The VTM software can be found at

<https://vcgit.hhi.fraunhofer.de/jvet/VVCSoftware_VTM/>

The BMS software can be found at:

<https://vcgit.hhi.fraunhofer.de/jvet/VVCSoftware_BMS/>

After two release candidates, VTM 2.0 and BMS 2.0 were tagged on August 20, 2018. VTM 2.0.1 and BMS 2.0.1 were released on August 23, 2018 to fix an encoder bug in the affine search, which was affecting people’s ability to debug the software (different results were produced by release and debug builds of the code). This version reflects all normative changes affecting VTM. VTM 2.0/2.0.1 were derived from BMS 2.0/2.0.1 by stripping the JEM\_TOOLS macro.

Changes related to VTM/BMS 1.1 include:

* K0054: high-precision PSNR reporting
* K0063: PDPC
* K0072: trellis coded quantization
* K0122: DC prediction
* K0154: high-precision distortion
* K0184: Affine MC
* K0190: CCLM
* K0220: Encoder speedup
* K0230: Dual coding tree
* K0251: extended QP range
* K0261: SW cleanup
* K0346: ATMVP
* K0351: TT restriction
* K0352: Encoder optimization of merge
* K0357: AMVR
* K0371: ALF
* K0312: additional decoder stats
* K0238: SAO greedy merge encoder option
* K0500: wide angular intra prediction
* K0554: boundary handling
* K0556: maximum TT size is 64
* K1000: simplified EMT
* 67 intra modes with 3 MPMs
* Various deblocking fixes
* -ipp options now adds a / in path if needed
* Increase chroma QP with dual coding trees are used
* Remove type aliases such as Int, Void, etc.
* Updated license text (include year 2018)

VTM 2.1 and BMS 2.1 were tagged on September 14, 2018, with the following changes. All BMS only adoptions were added to BMS 2.1, as well as encoder only changes. This includes:

* K0076: CPR
* K0149: Block statistics
* K0157: Composite long term reference
* K0206: Adaptive QP
* K0217: DMVR
* K0248: Generalized biprediction
* K0390: Rate control
* K0485: BIO simplifications
* Various fixes

VTM 2.1 was extracted from BMS 2.1 by stripping the JEM\_TOOLS macro and all new BMS only tool macros.

Development has proceeded beyond to include bug fixes and code cleanup. At the beginning of the 12th meeting, several merge requests are still pending, including:

* Update to K0149 block statistics
* K0325: trim NAL unit types
* High-precision MV storage

A script for extracting VTM from BMS is available at:

<https://vcgit.hhi.fraunhofer.de/jvet/VTM-Extraction>

The following shows VTM 2.0.1 performance over HM 16.19:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **All Intra Main10** | | | | |
|  | **Over HM-16.19** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 | -21.06% | -34.57% | -30.32% | 1159% | 173% |
| Class A2 | -19.69% | -21.89% | -15.92% | 1875% | 173% |
| Class B | -16.13% | -21.05% | -26.44% | 1968% | 169% |
| Class C | -15.91% | -20.04% | -22.88% | 2659% | 163% |
| Class E | -19.35% | -24.07% | -26.37% | 1432% | 152% |
| **Overall** | -18.03% | -23.72% | -24.53% | 1812% | 166% |
| Class D | -13.46% | -16.38% | -17.33% | 3005% | 162% |
| Class F (optional) | -16.25% | -22.40% | -24.46% | 1600% | 157% |
|  |  |  |  |  |  |
|  | **Random Access Main 10** | | | | |
|  | **Over HM-16.19** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 | -25.28% | -39.70% | -39.66% | 375% | 134% |
| Class A2 | -28.23% | -35.57% | -30.28% | 367% | 141% |
| Class B | -22.87% | -36.14% | -36.37% | 357% | 123% |
| Class C | -17.84% | -27.96% | -29.42% | 397% | 114% |
| Class E |  |  |  |  |  |
| **Overall** | -23.08% | -34.56% | -33.96% | 373% | 126% |
| Class D | -16.96% | -24.96% | -26.30% | 394% | 135% |
| Class F (optional) | -19.10% | -27.29% | -28.48% | 216% | 105% |
|  |  |  |  |  |  |
|  | **Low delay B Main10** | | | | |
|  | **Over HM-16.19** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 |  |  |  |  |  |
| Class A2 |  |  |  |  |  |
| Class B | -18.95% | -29.95% | -29.01% | 359% | 132% |
| Class C | -15.72% | -24.65% | -25.44% | 389% | 134% |
| Class E | -20.61% | -27.77% | -30.08% | 197% | 116% |
| **Overall** | -18.29% | -27.64% | -28.09% | 317% | 129% |
| Class D | -15.61% | -21.03% | -21.69% | 356% | 143% |
| Class F (optional) | -19.42% | -30.27% | -31.24% | 200% | 110% |
|  |  |  |  |  |  |
|  | **Low delay P Main10** | | | | |
|  | **Over HM-16.19** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 |  |  |  |  |  |
| Class A2 |  |  |  |  |  |
| Class B | -23.62% | -33.55% | -33.02% | 330% | 138% |
| Class C | -17.89% | -26.00% | -26.78% | 354% | 136% |
| Class E | -24.19% | -32.29% | -34.82% | 173% | 117% |
| **Overall** | -21.85% | -30.72% | -31.39% | 288% | 132% |
| Class D | -17.12% | -22.26% | -22.65% | 317% | 141% |
| Class F (optional) | -19.60% | -29.82% | -30.99% | 189% | 115% |

The following table shows BMS 2.1 compared to VTM 2.0.1:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **All Intra Main10** | | | | |
|  | **Over BMS-2.0.1 VTM cfg** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 | -0.62% | -2.15% | -1.77% | 323% | 96% |
| Class A2 | -0.83% | -2.37% | -1.84% | 318% | 98% |
| Class B | -1.15% | -2.09% | -3.10% | 343% | 96% |
| Class C | -1.27% | -2.15% | -2.74% | 344% | 101% |
| Class E | -1.92% | -2.67% | -4.39% | 351% | 98% |
| **Overall** | -1.16% | -2.26% | -2.80% | 337% | 98% |
| Class D | -1.24% | -1.99% | -2.34% | 345% | 104% |
| Class F (optional) | -18.40% | -18.86% | -19.16% | 375% | 94% |
|  |  |  |  |  |  |
|  | **Random Access Main 10** | | | | |
|  | **Over BMS-2.0.1 VTM cfg** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 | -3.59% | -3.83% | -4.37% | 192% | 134% |
| Class A2 | -5.22% | -4.99% | -4.31% | 188% | 137% |
| Class B | -4.00% | -4.78% | -5.56% | 208% | 147% |
| Class C | -3.73% | -3.59% | -4.28% | 225% | 152% |
| Class E |  |  |  |  |  |
| **Overall** | -4.09% | -4.31% | -4.73% | 205% | 144% |
| Class D | -4.76% | -4.54% | -4.33% | 227% | 153% |
| Class F (optional) | -16.23% | -16.61% | -16.88% | 232% | 136% |
|  |  |  |  |  |  |
|  | **Low delay B Main10** | | | | |
|  | **Over BMS-2.0.1 VTM cfg** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 |  |  |  |  |  |
| Class A2 |  |  |  |  |  |
| Class B | -1.32% | -0.09% | -0.53% | 182% | 104% |
| Class C | -0.88% | 0.30% | 0.03% | 197% | 100% |
| Class E | -0.93% | -0.58% | -1.14% | 148% | 101% |
| **Overall** | -1.08% | -0.08% | -0.49% | 177% | 102% |
| Class D | -0.62% | 1.33% | -0.21% | 199% | 101% |
| Class F (optional) | -10.20% | -9.71% | -9.85% | 177% | 97% |
|  |  |  |  |  |  |
|  | **Low delay P Main10** | | | | |
|  | **Over BMS-2.0.1 VTM cfg** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 |  |  |  |  |  |
| Class A2 |  |  |  |  |  |
| Class B | -0.92% | 0.19% | 0.14% | 195% | 103% |
| Class C | -0.68% | 0.17% | -0.19% | 209% | 103% |
| Class E | -0.57% | 0.02% | -1.23% | 157% | 100% |
| **Overall** | -0.75% | 0.14% | -0.31% | 189% | 102% |
| Class D | -0.58% | 0.66% | 0.13% | 208% | 100% |
| Class F (optional) | -8.88% | -9.28% | -9.32% | 197% | 99% |

Full results for VTM and BMS were attached to this AHG report as Excel files.

Difficulties in VTM/BMS software development

Move to Gitlab

In general, moving to git and Gitlab turned out to be challenging as people had to learn a new workflow and a different set of tools. With proponents (and software coordinators) getting more familiar with these tools, these difficulties should resolve with time.

BMS and VTM

The coexistence of BMS and VTM created some confusion. All implementations were performed in BMS, while VTM was extracted by removing macros. Tools that were moved from BMS to VTM had to be moved out of the JEM\_TOOLS macro. This created some difficulties because proponents sometimes were not aware where the code ended up. For BMS/VTM 2.0 even some non-CTC encoder code is missing in the tagged version.

Unclear meeting decisions

While most meeting decisions are straightforward, there were a few cases that presented surprises. Such surprises may come from a variety of factors, including imprecise meeting notes, adopted contributions lacking detail, mismatches between CE descriptions and actual experiments, unforeseen interactions between decisions.

Two examples include:

K0371: ALF

K0076: CPR created some side effects with other tools because the slice type was changed from I\_SLICE to P\_SLICE. Tools that depended on the slice type ended up using the wrong decisions.

CE software

For each CE a group was created in GitLab and CE coordinators were given owner rights to the group. This way they could clone VTM, BMS, or both as required, create branches for different tests and assign user access to the group themselves.

The CE development workflow is described at:

https://vcgit.hhi.fraunhofer.de/jvet/VVCSoftware\_BMS/wikis/Core-experiment-development-workflow

Guidelines for software development

The final version of the guidelines for software development was uploaded as JVET-K1003. There are no changes proposed at this meeting. However, the addition of guidelines for SIMD code would be beneficial.

Bug tracking

The bug tracker for VTM, BMS and specification text is located at:

https://jvet.hhi.fraunhofer.de/trac/vvc

The bug tracker uses the same accounts as the HM software bug tracker. Users may need to log in again due to the different sub-domain. For spam fighting reasons account registration is only possible at the HM software bug tracker at

https://hevc.hhi.fraunhofer.de/trac/hevc

Please file all issues related to the VVC reference software into the bug tracker. Try to provide all the details, which are necessary to reproduce the issue. Patches for solving issues and improving the software are always appreciated.

The AHG recommended to:

* Continue to develop the VTM reference software
* Cease development of the BMS
* Encourage people to test VTM software more extensively outside of common test conditions.
* Encourage people to report all (potential) bugs that they are finding.
* Encourage people to submit bitstreams/test cases that trigger bugs in VTM.
* Develop guidelines for SIMD code

In the discussion, it was noted that a benefit of the new GitLab system is that it is now easier to submit proposed code improvements, and this was encouraged.

The bug tracking system has the ability to attach data files.

It was commented that it is important to make sure that that bug reports contain the necessary information to reproduce the bug.

It was commented that there would be less of a burden on CE coordinators if some sort of shared account was established for read access or if every account had read access to all CEs.

It was agreed to set up a shared account for MPEG members (using the current typical MPEG credentials) and a shared account for VCEG members, each of which would change periodically.

It was commented that people who submit code changes really need to review the changes they are submitting. In some cases, people don’t seem to be doing that.

It was commented that in some cases the SIMD code was not well written and sometimes not even faster than the equivalent non-SIMD code. Generally, we don’t want much SIMD code.

Regarding the question of whether to continue to have a BMS – as shown above, the BMS is only significantly better than the VTM for the RA case, and that’s only about 4%. The gap for the other cases is only about 1%. It was agreed to discontinue the BMS.

[JVET-L0004](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4254) JVET AHG report: Test material and visual assessment (AHG4) [V. Baroncini, R. Chernyak, P. Hanhart, A. Norkin, T. Suzuki, J. Ye]

This document reports the work of the JVET ad hoc group on test material and visual assessment (AHG4) between the 11th meeting in Ljubljana, SI (10–18 July 2018) and the 12th meeting in Macao, CN (3–12 October 2018).

The test sequences used for CfP (JVET-H1002) are available on ftp://jvet@ftp.ient.rwth-aachen.de in directory “/jvet-cfp” (accredited members of JVET may contact the JVET chairs for login information).

Due to copyright restrictions, the JVET database of test sequences is only available to accredited members of JVET (i.e. members of ISO/IEC MPEG and ITU-T VCEG).

Related contributions to this meeting are as follows.

* JVET-L0547 “Blender Foundation/Animation Studio test sequences", F. Siddi (Blender Animation Studio), T. Roosendaal (Blender Foundation).

The AHG recommended:

* To review all related contribution
* To continue to collect new test sequences available for JVET with licensing statement

[JVET-L0005](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4665) JVET AHG Report: Memory bandwidth consumption of coding tools (AHG5) [R. Hashimoto, Y. He, T. Ikai, X. Li, H. Yang]

The document summarizes activities of AHG on memory bandwidth consumption of coding tools between the 11th and the 12th JVET meetings.

There was no related email discussion during this meeting cycle.

Contributions to this meeting are as follows.

* JVET-L0055 “CE4-related: Redundant Removal for ATMVP”, A. Tamse, M. W. Park, S. Jeong, K. Choi (Samsung)
* JVET-L0104 “AHG5: Reducing VVC worst-case memory bandwidth by restricting bi-directional 4x4 inter CUs/Sub-blocks”, Y.-W. Chen, X. Wang (Kwai Inc.)
* JVET-L0122 “AHG5: Reduction of worst case memory bandwidth”, J. Li, R.-L. Liao, C. S. Lim (Panasonic)
* JVET-L0319 “CE4-related: Sub-block MV clipping in planar motion vector prediction”, M. Gao, X. Li, M. Xu, S. Liu (Tencent)
* JVET-L0371 “CE4-related: Reducing worst case memory bandwidth in inter prediction”, H. Chen, H. Yang, J. Chen (Huawei)
* JVET-L0396 “CE4-related: Affine restrictions for the worst-case bandwidth reduction”, L. Pham Van, W.-J. Chien, H. Huang, V. Seregin, M. Karczewicz (Qualcomm)

AHG5 thanked the AHG13 activity to evaluate memory bandwidth in tool on/off tests.

See JVET-L0013 report to confirm the result.

The AHG recommended to review all related contribution

[JVET-L0006](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4346) JVET AHG Report: 360 video conversion software development (AHG6) [Y. He, K. Choi]

The document summarizes activities on 360-degree video content conversion software development between the 11th (10 – 18 Jul. 2018) and the 12th (3 – 12 Oct. 2018) JVET meetings.

The 360Lib-7.0 software package included following changes:

* Projection format:
  + Hybrid equi-angular cubemap (JVET-K0131)
* Software updates:
  + Added PSNR output in hex format for spherical metrics;
* Configurations:
  + Added those HEC related configuration files;
  + Updated the software manual for HEC and some improvements for CMP based on bug report #64
* 360Lib-7.0 related release:
  + 360Lib-7.0rc1 with support of VTM-2.0 and BMS-2.0 was released on Aug. 22, 2018;
  + 360Lib-7.0 with support of VTM-2.0.1 and BMS-2.0.1 was released on Aug 29, 2018;

The 360Lib software is developed using a Subversion repository located at:

<https://jvet.hhi.fraunhofer.de/svn/svn_360Lib/>

The released version of 360Lib-7.0 can be found at:

<https://jvet.hhi.fraunhofer.de/svn/svn_360Lib/tags/360Lib-7.0/>

360Lib-7.0 testing results can be found at:

[ftp.ient.rwth-aachen.de/testresults/360Lib-7.0](ftp://ftp.ient.rwth-aachen.de/testresults/360Lib-7.0)

360Lib bug tracker

<https://hevc.hhi.fraunhofer.de/trac/jem/newticket?component=360Lib>

360Lib-7.0 results

Projection format comparisons are shown below using VTM-2.0.1 and BMS-2.1 according to the 360° video CTC (JVET-K1012). The first table lists the VTM-2.0.1 CMP coding performance compared to VTM-2.0.1 PERP coding. The second table compares the BMS-2.1 CMP coding with BMS-2.1 PERP coding. The third and fourth tables are for VTM-2.0.1 and BMS-2.1 comparisons using PERP and CMP projection formats. The fifth and sixth tables are for VTM-2.0.1 and HM-16.16 comparisons using PERP and CMP projection formats.

**VTM-2.0.1 CMP vs PERP (VTM-2.0.1 PERP coding as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **CMP over PERP (VTM-2.0.1)** | | | | | |
|  | **End-to-end WS-PSNR** | | | **End-to-end S-PSNR-NN** | | |
|  | Y | U | V | Y | U | V |
| Class S1 | -3.35% | -0.45% | -1.79% | -3.40% | -0.48% | -1.84% |
| Class S2 | 1.72% | 3.83% | 3.39% | 1.72% | 3.87% | 3.43% |
| **Overall** | -1.32% | 1.26% | 0.28% | -1.35% | 1.26% | 0.27% |

**BMS-2.1 CMP vs PERP (BMS-2.1 PERP coding as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **CMP over PERP (BMS-2.1)** | | | | | |
|  | **End-to-end WS-PSNR** | | | **End-to-end S-PSNR-NN** | | |
|  | Y | U | V | Y | U | V |
| Class S1 | -3.13% | -0.25% | -1.25% | -3.17% | -0.29% | -1.27% |
| Class S2 | 2.23% | 4.70% | 3.92% | 2.23% | 4.76% | 3.97% |
| **Overall** | -0.98% | 1.73% | 0.82% | -1.01% | 1.73% | 0.82% |

**BMS-2.1 PERP vs VTM-2.0.1 PERP (VTM-2.0.1 PERP coding as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **PERP – BMS-2.1 Over VTM-2.0.1** | | | | | |
|  | **End-to-end WS-PSNR** | | | **End-to-end S-PSNR-NN** | | |
|  | Y | U | V | Y | U | V |
| Class S1 | -2.86% | -3.95% | -5.49% | -2.86% | -3.94% | -5.49% |
| Class S2 | -4.54% | -5.54% | -6.12% | -4.54% | -5.54% | -6.13% |
| **Overall** | -3.53% | -4.58% | -5.74% | -3.53% | -4.58% | -5.75% |

**BMS-2.1 CMP vs VTM-2.0.1 CMP (VTM-2.0.1 CMP coding as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **CMP – BMS-2.1 Over VTM-2.0.1** | | | | | |
|  | **End-to-end WS-PSNR** | | | **End-to-end S-PSNR-NN** | | |
|  | Y | U | V | Y | U | V |
| Class S1 | -2.60% | -3.75% | -4.92% | -2.60% | -3.74% | -4.91% |
| Class S2 | -3.94% | -4.59% | -5.47% | -3.95% | -4.59% | -5.47% |
| **Overall** | -3.14% | -4.09% | -5.14% | -3.14% | -4.08% | -5.13% |

**VTM-2.0.1 PERP vs HM-16.16 PERP (HM-16.16 PERP coding as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **VTM-2.0.1 PERP - Over HM-16.16 PERP** | | | | | |
|  | **End-to-end WS-PSNR** | | | **End-to-end S-PSNR-NN** | | |
|  | Y | U | V | Y | U | V |
| Class S1 | -18.70% | -37.62% | -37.34% | -18.69% | -37.63% | -37.30% |
| Class S2 | -25.66% | -41.67% | -41.83% | -25.65% | -41.70% | -41.85% |
| **Overall** | -21.48% | -39.24% | -39.14% | -21.47% | -39.25% | -39.12% |

**VTM-2.0.1 CMP vs HM-16.16 CMP (HM-16.16 CMP coding as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **VTM-2.0.1 CMP - Over HM-16.16** | | | | | |
|  | **End-to-end WS-PSNR** | | | **End-to-end S-PSNR-NN** | | |
|  | Y | U | V | Y | U | V |
| Class S1 | -16.87% | -34.74% | -34.94% | -16.86% | -34.78% | -34.97% |
| Class S2 | -24.16% | -40.11% | -40.52% | -24.15% | -40.13% | -40.55% |
| **Overall** | -19.79% | -36.88% | -37.18% | -19.78% | -36.92% | -37.20% |

The AHG recommended:

* To continue software development of the 360Lib software package.
* To generate CTC VTM anchors according to 360° video CTC, and finalize the reporting template for the common test conditions.

[JVET-L0007](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4698) JVET AHG report: Coding of HDR/WCG material (AHG7) [A. Segall, W. Husak, E. François, D. Rusanovskyy]

This document summarizes the activity of AHG7: Coding of HDR/WCG Material between the 11th meeting in Ljubljana, SI (10–18 July 2018) and the 12th meeting in Macao, CN (3–12 October 2018).

The AHG used the main JVET reflector, jvet@lists.rwth-aachen.de, with an [AHG7] indication on message headers. The primary activity of the AhG was related to the mandates of preparing for expert viewing of HDR content at the 12th JVET meeting. This work is described in the following subsection.

During the AHG study period, it was expressed by some participants of CE12 that it may be beneficial to perform expert viewing of HDR sequences at the 12th JVET meeting. In response to that request, the chairs reached out to multiple companies to request an available display. Unfortunately, no entity was able to provide a display for the Macao meeting.

Furthermore, as a result of the coordination activity, it appears that HDR displays could be provided for European and/or North American locations. However, it may be challenging to have a suitable display for the 13th JVET meeting as well, as that meeting is in Marrakech, MA. The group may want to consider counter-measures during the 12th meeting. Examples could include requesting the support the MPEG Test Chair and/or scheduling a face-to-face meeting of the AhG to perform expert viewing. Cross-checkers are also requested to perform visual tests in their lab and to report their observations.

There were 8 contributions identified as related to HDR video coding:

JVET-L0032 CE12: Summary report on mapping functions [E. François, D. Rusanovskyy, P. Yin

JVET-L0205 CE12: report of CE12-1 on out-of-loop dynamic range adaptation [E. François, C. Chevance, F. Hiron (Technicolor), D. Rusanovskyy, A.K. Ramasubramonian, M. Karczewicz (Qualcomm),

JVET-L0167 AHG7: Subjective Quality Evaluation of VVC HDR sequences on UHD TV [A. DSouza, C. Pujara, R. Gadde, K. Choi, K. P. Choi (Samsung)

JVET-L0206 CE12: report of CE12-3 and CE12-5 on in-loop refinement [E. François, C. Chevance, F. Hiron (Technicolor)

JVET-L0245 CE12-2: HDR In-loop Reshaping [Taoran Lu, Fangjun Pu, Peng Yin, Walt Husak, Sean McCarthy, Tao Chen (Dolby)

JVET-L0246 CE12-4: SDR In-loop Reshaping [Fangjun Pu, Taoran Lu, Peng Yin, Walt Husak, Sean McCarthy, Tao Chen (Dolby)

JVET-L0247 CE12-related: Universal low complexity reshaper for SDR and HDR video [Taoran Lu, Sean McCarthy, Fangjun Pu, Peng Yin, Walt Husak, Tao Chen (Dolby)

JVET-L0490 CE12-related: HDR Coding with Backward Compatibility Options [Pankaj Topiwala, Madhu Krishnan, Wei Dai (FastVDO)

The AHG recommends the following:

Review all input contributions

Consider HDR display counter measures for the JVET 13th meeting

[JVET-L0008](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4692) JVET AHG report: 360° video coding tools and test conditions (AHG8) [J. Boyce, K. Choi, P. Hanhart, J.-L. Lin]

This document summarizes the activity of AHG8: 360º video coding tools and test conditions between the between the 11th meeting in Ljubljana, SI (10–18 July 2018) and the 12th meeting in Macao, CN (3 – 12 Oct 2018).

There was no AHG email activity on the main jvet reflector, jvet@lists.rwth-aachen.de, with an [AHG8] indication on message headers.

There is one non-CE related contribution related to 360º video coding, which is listed below. In addition, CE13 on projection formats is related to 360º video coding, and has 21 contributions, which will be described in the CE report in JVET-L0033. There are 4 additional CE13-related contribution, listed below.

* CE13 contributions (21 contributions, not listed here; see the section on CE13)
* 360 video contributions not related to CE13
  + JVET-L0238 AHG8: Chroma sample location type support for 360Lib [P. Hanhart, Y. He, Y. Ye (InterDigital)]
* CE13-related contributions
  + JVET-L0166 CE13-related: Subjective Quality Improvement for RSP [A. Singh (Samsung)]
  + JVET-L0212 CE13-related: Results for experiments as CE13.3.2, CE13.4.3 and CE13.7.7 with PHEC and impact of rotation on the coding performance of PHEC [J. Sauer, M. Bläser (RWTH Aachen University)]
  + JVET-L0237 CE13-related: Adaptive frame packing using chroma sample location type 1 [P. Hanhart, Y. He, Y. Ye (InterDigital)]
  + JVET-L0423 CE13-related: HEC with in-loop filters using spherical neighbours [Xuchang Huangfu, Yule Sun, Lu Yu (Zhejiang Univ.)

The AHG recommends the following:

* Review input contributions
* Conduct informal subjective viewing of contributions
* Review common test conditions for 360° video, including objective metrics and viewports
* Review 360° video test material, and consider adding or replacing test sequences for common test conditions

[JVET-L0009](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4636) JVET AHG report: Neural Networks in Video Coding (AHG9) [S. Liu, B. Choi, K. Kawamura, Y. Li, L. Wang, P. Wu, H. Yang]

This document summarizes the activity of AHG9: Neural network in video coding between the 11th meeting Ljubljana, SI (10–18 July 2018) and the 12th meeting in Macao, CN (3 – 12 Oct 2018).

The AHG used the main JVET reflector, jvet@lists.rwth-aachen.de, with [AHG9] in message headers. There was no email exchange on the main reflector and some offline discussions among proponents, participants and outside JVET. Academia universities and labs continued showing interests in the subject of Neural Networks for video compression with questions such as complexity and practicability, etc.

Input documents (technical proposals) related to AHG9 were identified as:

* JVET-L0242 “AHG9: Dense Residual Convolutional Neural Network based In-Loop Filter”, [Y. Wang, Z. Chen, Y. Li (Wuhan Univ.), L. Zhao (Tencent)]
* JVET-L0383 “AHG9: Convolution Neural Network Filter” [K. Kawamura, Y. Kidani, S. Naito (KDDI)]

The AHG recommended:

* To review all related contributions
* To continue discussions about methodologies and measurements for evaluating neural network related video coding tools

In the discussion, it was suggested that software availability would be helpful, including the tools for training. It was commented that it would not be feasible to have a CE until there is software.

[JVET-L0010](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4654) JVET AHG report: Encoding algorithm optimizations (AHG10) [A. Duenas, A. M. Tourapis, C. Helmrich, S. Ikonin, A. Norkin, R. Sjöberg]

The document summarizes the activities of the AHG on Encoding algorithm optimizations between the 11th meeting in Ljubljana, SI (10–18, July 2018) and the 12th meeting in Macao, CN (3–12, October 2018).

The following input documents were identified to be related to the AHG:

* JVET-L0210: CE 7: Adaptive quantization via perceptually optimized QP adaptation (Test 7.2.6) by Fraunhofer HHI
  + In JVET-H0047, the authors proposed a CTU-wise subjectively optimized QP adaptation (QPA) along with a correspondingly weighted PSNR (WPSNR) distortion measure. This QPA approach was further improved in JVET-K0206 and accepted for integration into (and optional activation in) the VTM/BMS software. Note that this is a non-normative encoder optimization – the delta-QP values are signalled in a HEVC-like fashion.
  + This document reports on Bjøntegaard delta (BD) PSNR and MS-SSIM results gathered from comparative measurements between VTM 2.0.1 with activated perceptual QPA and VTM 2.0.1 with fixed-QP encoding.
* JVET-L0241: AHG10: Adaptive lambda ratio estimation for rate control in VVC by Wuhan University and Tencent
  + This contribution presents some modifications based on the current rate control scheme proposed in JVET-K0390. With the proposed adaptive lambda ratio estimation algorithm, when using the anchor bit rate of BMS2.1 with VTM configuration as the target, there are X%/X%/X% for Y/U/V coding efficiency improvements in random access configuration when compared with the rate control algorithm in K0390.
* JVET-L0365: MS-SSIM as an additional metric
  + This contribution proposes to include the MS-SSIM metric as additional metric in VTM and make MS-SSIM Y mandatory in the CTC for SDR video. A patch for MS-SSIM integrated into VTM 2.0.1 and an Excel template for the CTC for SDR video are provided.

The AHG recommended that the related input contributions be reviewed and to further continue the study of encoding algorithm optimizations in JVET.

[JVET-L0011](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4638) JVET AHG report: Screen Content Coding (AHG11) [S. Liu, J. Boyce, Y. Sun, M. Zhou]

This document summarizes the activity of AHG11: Screen Content Coding between the 11th meeting Ljubljana, SI (10–18 July 2018) and the 12th meeting in Macao, CN (3–12 October 2018).

The AHG used the main JVET reflector, jvet@lists.rwth-aachen.de, with [AHG11] in message headers. The AHG worked closely with CE8 (CPR) and CE15 (Palette) to discuss about screen content tool compression benefits and especially complexity impacts. Some hardware experts (Broadcom and Ubilinx) provided valuable inputs. Through discussions it was agreed that some constraints may be imposed on CPR to make it more implementation friendly especially for hardware designs, such as,

* Allow CPR compensated only from the current CTU
* Allow CPR compensated only from the current CTU and the CTU to its left
* Exclude the current CTU and the two CTUs to its left from CPR compensation area
* Exclude the current CTU and the two CTUs to its left from CPR compensation area. In addition, disable all loop-filters
* Exclude the current CTU and the CTU to its left from CPR compensation area
* Exclude the current CTU and the CTU to its left from CPR compensation area. In addition, disable all loop-filters
* And use integer vectors for CPR of chroma

Details are discussed in CE8 report.

The new test sequence “ArenaOfValor” (1920x1080 60fps) which was adopted in the last meeting was included in CTC Class F and used for SCC tool tests.

Input documents related to AHG11 were summarized as follows.

* CPR related contributions
  + JVET-L0041 “Non-CE8: Rotate Intra Block Copy”, Z. Zhang, V. Sze (MIT)
  + JVET-L0077 “CE8: Intra Region-based Template Matching (Test 8.1)”, G. Venugopal, K. Müller, H. Schwarz, D. Marpe, T. Wiegand (HHI)
  + JVET-L0159 “Non-CE8: Block vector predictor for CPR”, J. Nam, J. Lim, S. Kim (LGE)
  + JVET-L0290 “CE8: CPR mode with dual-tree support (Test CE8.2)”, X. Xu, X. Li, S. Liu (Tencent)
  + JVET-L0293 “CE8: CPR mode with local search ranges (Test CE8.3.1 and CE8.3.2)”, X. Xu, X. Li, S. Liu (Tencent)
  + JVET-L0295 “CE8: CPR mode with non local search ranges (Test CE8.3.3, CE8.3.4, CE8.3.5 and CE8.3.6)”, X. Xu, X. Li, S. Liu (Tencent)
  + JVET-L0297 “CE8-related: CPR mode with local search range optimization”, X. Xu, X. Li, S. Liu (Tencent), E. Chai (Ubilinx)
  + JVET-L0299 “CE8-related: CPR mode with merge mode improvements”, X. Xu, X. Li, M. Gao, J. Ye, S. Liu (Tencent)
  + JVET-L0404 “CE8-related: Restrictions for the search area of the CPR blocks in CPR”, L. Pham Van, V. Seregin, W.-J. Chien, T. Hsieh, M. Karczewicz (Qualcomm)
* Palette related contributions
  + JVET-L0213 “CE15-related: Combination of palette mode and intra prediction”, Y.-C. Sun, J. An, J. Lou (Alibaba)
  + JVET-L0307 “CE15-related: Palette index map scan order constraints”, J. Ye, X. Li, S. Liu, X. Xu (Tencent)
  + JVET-L0308 “CE15-related: Palette mode when dual-tree is enabled”, J. Ye, X. Li, S. Liu, X. Xu (Tencent)
  + JVET-L0336 “CE15-2: Palette mode of HEVC SCC”, Y.-H. Chao, H. Wang, V. Seregin, M. Karczewicz (Qualcomm), Y.-C. Sun, J. An, J. Lou (Alibaba)
  + JVET-L0344 “CE15-1: Palette mode”, Y.-C. Sun, J. An, J. Lou (Alibaba), Y.-H. Chao, H. Wang, V. Seregin, M. Karczewicz (Qualcomm)
  + JVET-L0427 “CE15-related: Separate Palette Coding for Luma and Chroma components”, R. Chernyak, S. Ikonin, J. Chen (Huawei)
  + JVET-L0451 “CE15-related: Palette predictor list enhancement”, J. Ye, X. Li, X. Xu, S. Liu (Tencent)
* Other related contributions
  + JVET-L0078 “AHG11: Block DPCM for Screen Content Coding”, M. Abdoli, G. Clare, F. Henry, P. Philippe (Orange)
  + JVET-L0185 “AHG11 & CE1-related: Luma 2xN and Nx2 Block Partitions Support”, J. An, Y.-C. Sun, J. Lou (Alibaba)

The AHG recommended:

* To review all related contributions
* To continue investigating SCC coding tool performance, complexity and interactions between themselves and with other coding tools
* To continue evaluating new test materials

[JVET-L0012](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4502) JVET AHG report: High-level parallelism and coded picture regions (AHG12) [T. Ikai, M. Coban, M. M. Hannuksela, H. M. Jang, R. Sjöberg, R. Skupin, Y.-K. Wang]

This document summarizes the activity of AHG12: High-level parallelism and coded picture regions between the 11th meeting Ljubljana, SI (10–18 July 2018) and the 12th meeting in Macao, CN (3–12 October 2018).

The AHG used the main JVET reflector, jvet@lists.rwth-aachen.de, with [AHG12] in message headers. No emails were exchanged in the reflector.

Input documents related to AHG12 were summarized as follows.

* JVET-L0110 On VVC HLS architecture and bitstream structure, S. Wenger (Tencent), Y.-K. Wang (Huawei), M. M. Hannuksela (Nokia), R. Sjöberg (Ericsson), S. Deshpande (Sharp)
* JVET-L0114 On slicing and tiling in VVC, Y.-K. Wang, Hendry, J. Chen, M. Sychev (Huawei), M. M. Hannuksela (Nokia)
* JVET-L0127 On VVC tile design, Yong HE, Yan Ye, Ahmed Hamza (InterDigital)
* JVET-L0182 Design goals for tiles, M. M. Hannuksela, A. Zare, M. Homayouni, R. Ghaznavi-Youvalari, A. Aminlou (Nokia)
* JVET-L0227 AHG 12: Sub-bitstream extraction/merging friendly slice address signalling
* JVET-L0306 On slices and tiles, M. M. Hannuksela (Nokia)
* JVET-L0359 AHG12: Flexible tile partitioning, Y. Yasugi, T. Ikai (Sharp)
* JVET-L0374 On Tile Information Signalling for VVC, S. Deshpande, Y. Yasugi (Sharp)
* JVET-L0394 On Conflicting Use of Tiles, Stephan Wenger
* JVET-L0415 Tile groups for VVC, R.Sjöberg, M. Damghanian, M. Pettersson (Ericsson)

The AHG recommends:

* To review all related contributions
* To discuss the followings in the meeting and reach basic or initial agreement
  + Bitstream structure (e.g. necessity of slices, header structures for tiles/pictures)
  + Independent decoding picture regions and its extraction property (e.g. motion constrained tile sets)
  + Tile partitioning structure

[JVET-L0013](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4704) JVET AHG report: Tool reporting procedure (AHG13) [W.-J. Chien, J. Boyce (co-chairs), R. Chernyak, K. Choi, R. Hashimoto, Y. He, Y.-W. Huang, S. Liu]

This document summarizes the activity of AHG13: “Tool reporting procedure” between the 11th Meeting in Ljubljana, SI (10–18 July 2018) and the 12th meeting in Macao, CN (3–12 Oct. 2018). Tool on/off experimental results vs. VTM and BMS anchors are provided for the tools specified in JVET-K1005, which include the VTM and BMS tools.

The initial version of JVET-K1005 “Methodology and reporting template for tool testing” was provided on Aug 3rd, with updates provided on Sept. 26th. The document contained a reporting template.

All tests described in JVET-J1005 were conducted. VTM tool tests were conducted on BMS-2.0.1 software with VTM configuration and BMS tool tests were conducted on BMS-2.1 software with VTM configuration (for tool on tests) and BMS configuration (for tool off tests).

The tested tools, testers, and cross-checkers are listed in the tables below.

[Update results with SAO]

List of adoptions included in VTM (Tool off test vs VTM anchor)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Tool Name** | **Abbrev. Name** | **Document reference(s)** | **AI** | **RA** | **LD** | **Tester** | **Crosscheck** |
| Chroma separate tree with chroma QPOffset=0 | CST+CQP0 | JVET-K0230, JVET-K0556 | X | X | X | S. Liu (Tencent) | T. D. Chuang (MediaTek) |
| Chroma separate tree with chroma QPOffset=1 | CST+CQP1 | JVET-K0230, JVET-K0556 | X | X | X | S. Liu (Tencent) | T. D. Chuang (MediaTek) |
| Frame boundary partition | FBP | JVET-K0554 | X | X | X | S. Liu (Tencent) | R. Chernyak (Huawei) |
| Dependent quantization | DQ | JVET-K0072 | X | X | X | Y. He  (InterDigital) | K. Choi (Samsung) |
| Sign data hiding\* | SDH | JVET-K0310 | X | X | X | R. Chernyak (Huawei) | P. Yin (Dolby) |
| Cross-component linear model | CCLM | JVET-K0190 | X | X | X | R. Chernyak (Huawei) | W.-J. Chien (Qualcomm) |
| Multiple transform selection | MTS | JVET-K0171, JVET-K0173, JVET-K0096 | X | X | X | S. Liu (Tencent) | K. Choi (Samsung) |
| 67 intra prediction mode +3 MPM intra mode coding | 67IPM | JVET-K0529, JVET-K0368 | X | X | X | S. Liu (Tencent) | K. Choi (Samsung) |
| Position dependent prediction combination | PDPC | JVET-K0063 | X | X | X | R. Chernyak (Huawei) | W.-J. Chien (Qualcomm) |
| Wide angle intra prediction | WIP | JVET-K0500 | X | X | X | K. Choi (Samsung) | R. Chernyak (Huawei) |
| Adaptive loop filter | ALF | JVET-K0371 | X | X | X | Y. He  (InterDigital) | W.-J. Chien (Qualcomm) |
| Partition restriction | PR | JVET-K0351 | X | X | X | W.-J. Chien (Qualcomm) | E. Francois (Technicolor) |
| Deblocking on 64 pixels sample TU | DB64 | JVET-K0307, JVET-K0237, JVET-K0369, JVET-K0232, JVET-K0315 | X | X | X | K. Choi (Samsung) | R. Chernyak (Huawei) |
| Deblocking on 8x8 grid | DB8x8 |  | X | X | X | W.-J. Chien (Qualcomm) | Y. He  (InterDigital) |
| QP upper bound increase\*\* | MaxQP | JVET-K0251 | X | X | X | T. D. Chuang (MediaTek) | E. Francois (Technicolor) |
| Split restriction TT when size is larger than 64 | TT64 | JVET-K0230, JVET-K0556 | X | X | X | K. Choi (Samsung) | T. D. Chuang (MediaTek) |
| Implicit split QT 128x128 to 64x64 in I slice | QT128 | JVET-K0230, JVET-K0556 | X | X | X | K. Choi (Samsung) | T. D. Chuang (MediaTek) |
| DC average computation | DC | JVET-K0122 | X | X | X | R. Chernyak (Huawei) | W.-J. Chien (Qualcomm) |
| Affine motion model | AFF | JVET-K0184, JVET-K0337 |  | X | X | Y. He  (InterDigital) | R. Chernyak (Huawei) |
| Alternative temporal motion vector prediction | ATMVP | JVET-K0346 |  | X | X | Y. He  (InterDigital) | W.-J. Chien (Qualcomm) |
| Adaptive motion vector resolution | AMVR | JVET-K0357 |  | X | X | S. Liu (Tencent) | W.-J. Chien (Qualcomm) |

Table 2 List of tools included in BMS but not included in VTM

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Tool Name** | **Abbrev. Name** | **Document reference(s)** | **VTM anchor, tool on/off** | **BMS anchor, tool on/off** | **AI** | **RA** | **LD** | **Tester** | **Crosscheck** |
| Intra block copy | CPR | JVET-K0076 | on | off | X | X | X | S. Liu (Tencent) | R. Chernyak (Huawei) |
| Non-separable Secondary transform | NSST | JVET-D0120 | on | off | X | X | X | Y. He  (InterDigital) | W.-J. Chien (Qualcomm) |
| Bi-directional optical flow | BIO | JVET-K0485 | on | off |  | X | X | Y. He  (InterDigital) | K. Choi (Samsung) |
| Generalized bi-prediction | GBI | JVET-K0248 | on | off |  | X | X | Y. He  (InterDigital) | E. Francois (Technicolor)/ T. D. Chuang (MediaTek) |
| Decoder side motion refinement | DMVR | JVET-K0217 | on | off |  | X | X | Y. He  (InterDigital) | K. Choi (Samsung) |

The results of the tests are summarized in Table 3 below. The attached spreadsheet provides additional data. Scatter plots are also provided for the tested tools in random access configuration, comparing PSNR-Y based bd-rate on the Y axis vs. each of Enc runtime ratio, Dec runtime ratio, and a weighted average of Enc and Dec runtime ratio, (Enc + a\*Dec)/(a+1), with a configurable weight, a. The exemplary weighting is set to 6 and can be adjusted in the spreadsheet attached to this report.

Full experimental results and configuration files can be found at the link below:

https://hevc.hhi.fraunhofer.de/svn/svn\_VVCTestConfig/branches/VTM-2.0/

There was no bitrate or PSNR differences between testers and cross-checkers.

Encoder and Decoder runtime ratios provided by both the testers and cross-checkers are included in the reporting template, to identify if there were significant runtime differences. The largest runtime differences were found for TRM (MTS+4x4 NSST), where the tester uses GCC 6.3.0 and SIMD=SSE42 and the crosschecker uses GCC 4.8.3 and SIMD=AVX.

Simulation results in all intra configuration (AI) of VTM tool “off” test. (VTM anchor)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | AI | | | | | | |
| Abbreviation | BDR-Y | BDR-U | BDR-V | Tester EncTime | Tester DecTime | XChecker EncTime | XChecker DecTime |
| CST\_CQP0 | 2.11% | -3.65% | -3.26% | 131% | 98% | 129% | 101% |
| CST\_CQP1 | 0.15% | 11.44% | 11.56% | 129% | 98% | 127% | 100% |
| FBP | 0.08% | 0.37% | 0.35% | 95% | 94% | 99% | 99% |
| DQ | 2.44% | 2.03% | 1.75% | 76% | 102% | 77% | 102% |
| SDH | 0.75% | 1.22% | 1.15% | 97% | 101% | 95% | 101% |
| CCLM | 2.15% | 16.75% | 15.49% | 99% | 100% | 99% | 98% |
| MTS | 2.84% | 2.32% | 2.36% | 42% | 81% | 44% | 84% |
| 67IPM | 0.51% | 0.52% | 0.50% | 93% | 96% | 97% | 102% |
| PDPC | 1.11% | 0.78% | 0.65% | 97% | 93% | 97% | 93% |
| WIP | 0.20% | 0.18% | 0.24% | 101% | 104% | 100% | 98% |
| ALF | 2.46% | 3.24% | 3.17% | 100% | 88% | 99% | 87% |
| PR | 0.00% | 0.00% | 0.00% | 99% | 100% | 100% | 105% |
| DB64 | 0.00% | 0.00% | 0.00% | 99% | 100% | 100% | 98% |
| DB8x8 | 0.18% | 0.00% | -0.01% | 99% | 100% | 100% | 100% |
| MaxQP | 0.00% | 0.00% | 0.00% | 100% | 99% | 101% | 100% |
| TT64 | 0.00% | 0.00% | 0.00% | 101% | 102% | 101% | 102% |
| QT128 | 0.03% | 0.09% | 0.10% | 98% | 102% | 100% | 101% |
| DC | 0.02% | 0.01% | 0.02% | 100% | 98% | 100% | 99% |

Simulation results in random access configuration (RA) of VTM tool “off” test. (VTM anchor)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | RA | | | | | | |
| Abbreviation | BDR-Y | BDR-U | BDR-V | Tester EncTime | Tester DecTime | XChecker EncTime | XChecker DecTime |
| CST\_CQP0 | 0.30% | 2.05% | 2.27% | 101% | 100% | 102% | 104% |
| CST\_CQP1 | -0.87% | 14.99% | 15.21% | 100% | 100% | 102% | 104% |
| FBP | 0.39% | 0.56% | 0.49% | 92% | 95% | 97% | 101% |
| DQ | 2.18% | 1.20% | 0.82% | 91% | 101% | 92% | 102% |
| SDH | 0.54% | 0.86% | 0.86% | 99% | 100% | 98% | 101% |
| CCLM | 1.00% | 15.45% | 14.35% | 99% | 100% | 99% | 99% |
| MTS | 1.28% | 0.87% | 1.00% | 80% | 94% | 85% | 97% |
| 67IPM | 0.24% | 0.39% | 0.38% | 95% | 96% | 100% | 100% |
| PDPC | 0.63% | 0.31% | 0.16% | 98% | 98% | 98% | 98% |
| WIP | 0.10% | 0.11% | 0.20% | 100% | 100% | 99% | 99% |
| ALF | 4.66% | 3.36% | 2.73% | 100% | 83% | 100% | 85% |
| PR | 0.01% | 0.08% | -0.01% | 96% | 99% | 96% | 99% |
| DB64 | 0.03% | 0.02% | -0.04% | 100% | 100% | 100% | 100% |
| DB8x8 | -0.06% | 0.02% | -0.10% | 99% | 99% | 100% | 101% |
| MaxQP | 0.82% | 2.20% | 1.89% | 108% | 104% | 108% | 107% |
| TT64 | -0.23% | -0.21% | -0.24% | 111% | 96% | 114% | 104% |
| QT128 | 0.03% | 0.10% | 0.01% | 98% | 97% | 101% | 104% |
| DC | 0.01% | 0.07% | 0.02% | 100% | 99% | 100% | 100% |
| AFF | 3.79% | 2.72% | 2.64% | 86% | 92% | 86% | 93% |
| ATMVP | 0.66% | 0.68% | 0.52% | 100% | 100% | 100% | 98% |
| AMVR | 1.39% | 2.15% | 2.18% | 89% | 102% | 88% | 101% |

Simulation results in low delay B configuration (LDB) of VTM tool “off” test. (VTM anchor)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | LDB | | | | | | |
| Abbreviation | BDR-Y | BDR-U | BDR-V | Tester EncTime | Tester DecTime | XChecker EncTime | XChecker DecTime |
| CST\_CQP0 | 0.05% | -0.83% | -0.53% | 99% | 99% | 102% | 106% |
| CST\_CQP1 | -0.84% | 20.45% | 20.72% | 99% | 99% | 101% | 106% |
| FBP | 0.61% | 0.51% | 0.85% | 92% | 95% | 97% | 103% |
| DQ | 1.82% | 1.70% | 0.88% | 92% | 99% | 93% | 101% |
| SDH | 0.58% | 0.95% | 0.98% | 99% | 100% | 101% | 100% |
| CCLM | 0.03% | 3.99% | 3.68% | 100% | 100% | 100% | 102% |
| MTS | 0.36% | 0.41% | 0.48% | 90% | 98% | 95% | 98% |
| 67IPM | 0.06% | 0.25% | -0.08% | 96% | 100% | 102% | 100% |
| PDPC | 0.18% | 0.12% | -0.14% | 99% | 98% | 100% | 101% |
| WIP | 0.06% | 0.10% | -0.30% | 100% | 100% | 100% | 101% |
| ALF | 3.49% | 3.65% | 3.88% | 99% | 88% | 101% | 89% |
| PR | -0.02% | -0.13% | -0.13% | 97% | 102% | 93% | 91% |
| DB64 | -0.01% | -0.01% | -0.05% | 100% | 100% | 100% | 102% |
| DB8x8 | -0.15% | -0.13% | -0.27% | 100% | 101% | 100% | 99% |
| MaxQP | 0.53% | 2.09% | 1.92% | 104% | 102% | 103% | 102% |
| TT64 | -0.24% | -0.10% | -0.28% | 109% | 94% | 113% | 106% |
| QT128 | -0.04% | 0.07% | -0.23% | 99% | 94% | 102% | 106% |
| DC | -0.01% | 0.17% | -0.25% | 100% | 99% | 101% | 103% |
| AFF | 2.49% | 1.69% | 1.70% | 77% | 90% | 78% | 94% |
| ATMVP | 0.63% | 0.76% | 0.66% | 99% | 97% | 100% | 98% |
| AMVR | 0.66% | 1.18% | 1.23% | 89% | 99% | 82% | 101% |

Simulation results in all intra configuration (AI) of BMS tool “on” test. (VTM anchor)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | AI | | | | | | |
| Abbreviation | BDR-Y | BDR-U | BDR-V | Tester EncTime | Tester DecTime | XChecker EncTime | XChecker DecTime |
| CPR | -0.39% | -0.50% | -0.42% | 144% | 96% | 146% | 100% |
| NSST | -0.93% | -2.27% | -2.85% | 295% | 102% | 297% | 100% |

Simulation results in random access configuration (RA) of BMS tool “on” test. (VTM anchor)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | RA | | | | | | |
| Abbreviation | BDR-Y | BDR-U | BDR-V | Tester EncTime | Tester DecTime | XChecker EncTime | XChecker DecTime |
| CPR | -0.09% | -0.31% | -0.22% | 104% | 99% | 105% | 100% |
| NSST | -0.45% | -1.93% | -2.28% | 153% | 101% | 153% | 100% |
| BIO | -1.41% | -0.58% | -0.40% | 103% | 119% | 104% | 120% |
| GBI | -0.68% | -0.85% | -0.81% | 115% | 100% | 115% | 100% |
| DMVR | -1.65% | -1.74% | -1.82% | 104% | 122% | 104% | 122% |

Simulation results in low delay B configuration (LDB) of BMS tool “on” test. (VTM anchor)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | LDB | | | | | | |
| Abbreviation | BDR-Y | BDR-U | BDR-V | Tester EncTime | Tester DecTime | XChecker EncTime | XChecker DecTime |
| CPR | 0.07% | 0.17% | -0.01% | 108% | 94% |  |  |
| NSST | -0.15% | -1.05% | -1.73% | 123% | 102% | 126% | 99% |
| BIO | 0.00% | 0.00% | 0.00% | 100% | 100% | 100% | 99% |
| GBI | -0.34% | -0.35% | -0.37% | 92% | 99% | 112% | 100% |
| DMVR | 0.00% | 0.00% | 0.00% | 100% | 100% | 100% | 100% |

Simulation results in all intra configuration (AI) of BMS tool “off” test. (BMS anchor)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | AI | | | | | | |
| Abbreviation | BDR-Y | BDR-U | BDR-V | Tester EncTime | Tester DecTime | XChecker EncTime | XChecker DecTime |
| CPR | 0.26% | 0.28% | 0.22% | 144% | 96% | 146% | 100% |
| NSST | 0.87% | 2.20% | 2.86% | 295% | 102% | 297% | 100% |

Simulation results in random access configuration (RA) of BMS tool “off” test. (BMS anchor)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | RA | | | | | | |
| Abbreviation | BDR-Y | BDR-U | BDR-V | Tester EncTime | Tester DecTime | XChecker EncTime | XChecker DecTime |
| CPR | -0.02% | 0.17% | 0.20% | 104% | 99% | 105% | 100% |
| NSST | 0.45% | 1.98% | 2.50% | 153% | 101% | 153% | 100% |
| BIO | 0.98% | 0.28% | 0.14% | 103% | 119% | 104% | 120% |
| GBI | 0.60% | 0.69% | 0.68% | 115% | 100% | 115% | 100% |
| DMVR | 1.04% | 1.25% | 1.38% | 104% | 122% | 104% | 122% |

Simulation results in low delay B configuration (LDB) of BMS tool “off” test. (BMS anchor)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | LDB | | | | | | |
| Abbreviation | BDR-Y | BDR-U | BDR-V | Tester EncTime | Tester DecTime | XChecker EncTime | XChecker DecTime |
| CPR | -0.04% | -0.32% | -0.61% | 92% | 98% | 95% | 100% |
| NSST | 0.21% | 1.08% | 1.29% | 88% | 98% | 87% | 100% |
| BIO | 0.00% | 0.00% | 0.00% | 100% | 100% | 100% | 100% |
| GBI | 0.37% | 0.13% | 0.10% | 92% | 99% | 92% | 99% |
| DMVR | 0.00% | 0.00% | 0.00% | 100% | 100% | 100% | 99% |

Trade-offs of runtime versus gain were also included in the report.

Percentage of picture area and memory bandwidth results of VTM tool “off” test. (VTM anchor)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | AI | RA | | | LDB | | |
| Abbreviation | Percentage | Percentage | Ave mem BW | Max mem BW | Pixel usage | Ave mem BW | Max mem BW |
| CCLM | 49% | 4% |  |  | 1% |  |  |
| MTS | 54% | 5% |  |  | 2% |  |  |
| ALF | 64% | 69% |  |  | 57% |  |  |
| AFF |  | 12% | 101% | 106% | 14% | 100% | 106% |
| ATMVP |  | 11% | 94% | 100% | 10% | 103% | 115% |
| AMVR |  | 7% | 102% | 107% | 5% | 100% | 103% |

A related contribution was reported to be:

* JVET-L0201 AHG13 – Weighted Prediction vs Generalized Bi-prediction with Fade sequences [P. Bordes, E. François (Technicolor)]

The AHG recommended the following:

* Consider the reported tool test results during tool adoption decision making
* Review related contributions
* Refine list of tested tools and test methodology for the next meeting cycle
  + Consider the reported tool test results as a benchmark for CE tests
  + Consider including reporting of compute system information for testers and cross-checkers
  + Consider additional performance or complexity metrics

In the discussion, there was a discussion of “WIP” and “67IPM”. It was noted that these had been considered together as a package (measured above as providing 0.2%+0.6% for AI, about half that for RA) and part of the rationale was that these were not really adding significant decoder complexity. There had also been a bit more gain from an MPM design change proposed that was not included.

[JVET-L0014](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4548) JVET AHG report: Low-latency random access (AHG14) [J.-M. Thiesse, A. Duenas, K. Kazui, A. Tourapis]

This document summarizes activities of AhG on “low-latency random access” (a.k.a. “gradual decoder refresh”) between the 11th and the 12th JVET meetings.

AHG14 kickoff email was sent the 30th of July 2018, and since then there were several emails exchanges on the JVET reflector.

It was announced on the reflector that some software had been developed and was available for experiments (based on VTM 2.0.1) integrating encoder-only modifications supporting intra refresh. This software was distributed to interested parties and refined and was used in preparation of some contributions.

Relevant contributions to this meeting were as follows:

* JVET-L0079 AHG14: Study of methods for progressive intra refresh [K. Kazui (Fujitsu)]
* JVET-L0160 AHG14: Intra Refresh Test conditions and Anchors generation Proposal [J.-M. Thiesse, D. Nicholson, D. Gommelet (Vitec)]
* JVET-L0161 AHG14: Normative Intra Refresh Proposal [J.-M. Thiesse, D. Nicholson, D. Gommelet (VITEC)]

The AhG recommends:

* To review all related contributions.
* To consider the software modifications for integration on next VTM and BMS version.
* To add dedicated test conditions for Low-delay random access to the CTC.

In the discussion, there was discussion of the intended use and anticipated benefit. It was commented that it is important to understand the goals and test conditions.

Scalability was also mentioned as a possible approach.

It was asked whether products are currently using gradual decoder refresh. Yes, this has been (and remains) used in some products.

It was asked whether products are currently using constrained intra prediction? Yes, this has been (and remains) used in some products.

It was commented that this has an interaction with the use of slices and tiles, and whether we expect loss-concealed pictures to be displayed. Contribution JVET-L0110 was suggested to be relevant in that regard (proposing not to support traditional slices and other aspects).

[JVET-L0015](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4121) JVET AHG report: Bitstream decoding properties signalling (AHG15) [J. Boyce, J. Chen, S. Deshpande, M. Karczewicz, A. Tourapis, Y.-K. Wang, S. Wenger]

This document summarizes the activity of AHG15: Bitstream decoding properties signalling, between the between the 11th meeting in Ljubljana, SI (10–18 July 2018) and the 12th meeting in Macao, CN (3 – 12 Oct 2018).

The v1 version of this document contains the minutes of the first AHG conference call held 22 Aug 2018, and an attachment with the presentation shown during the call.

The v2 version of this document contains the minutes of the second AHG conference call held 20 Sept 2018.

The v3 version of this document includes additional contributions and AHG recommendations.

Email activity for the AHG was conducted on the main jvet reflector, jvet@lists.rwth-aachen.de, with an [AHG15] indication on message headers. The email activity was primarily regarding the two conference calls, announcing logistics, agenda, and availability of minutes and contributions.

A first AHG conference call was held 22 August 2018, with approximately 30 participants.

A second AHG conference call was held 20 September 2017, with approximately 35 participants.

The report contained additional information describing the discussions that took place on the conference calls.

Contributions reviewed at conference call #2:

* JVET-L0042 Example restriction flags for VVC [J. Samuelsson (Divideon)]
* JVET-L0043 AHG15: Hierarchical decoding property indications [M. M. Hannuksela (Nokia)]
* JVET-L0044 AHG15: Proposed interoperability point syntax [J. Boyce, Z. Deng, S. Wong, L. Xu (Intel)]

Additional contributions:

* JVET-L0270 Suggested restriction flag criteria [J. Samuelsson (Divideon)]

The AHG recommended:

* Review all contributions, including those initially discussed during the AHG conference calls
* Consider selection criteria for tool restriction syntax
* Consider decoding process impact of tool restriction syntax.
* Consider high-level syntax location(s) for tool restriction syntax

[JVET-L0016](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4343) JVET AHG report: Implementation studies (AHG16) [M. Zhou, E. Chai, K. Choi, S. Sethuraman, O. Hugosson, T. Hsieh, X. Xiu]

This document summarizes the activity of AHG16: implementation studies, between the 11th JVET meeting in Ljubljana, SI (0–18 July 2018) and the 12th JVET meeting in Macao, CN (3-12 October 2018)

There were few AHG email exchanges on the main JVET email reflector, jvet@lists.rwth-aachen.de, with an [AHG16] indication on message headers. A summary of the email activities was provided as follows:

* Complexity models for estimating some of decoder implementation issues
  + A few prior examples:
    - JVET-K0547 “BoG report on complexity analysis of long distance merge candidates and combined merge candidates”
    - JVET-K0521 “BoG report on ALF”
    - JVET-K0480 “A computational complexity analysis for DMVR”.
  + Mainly to count number of operations (e.g. adds, multiplies, comparisons, memory accesses) and memory footprint.
* (Hardware) decoder implementation careabouts
  + Whether a coding tool breaks or even completely destroys the decoder pipeline architecture. This can be determined by analyzing data dependency of the tool.
  + Whether a coding tool can provide sufficient throughput to meet the real-time requirements.
    - This is more difficult to analyze, sometimes needs to code the tool in RTL.
    - The entropy decoding and the intra prediction/reconstruction loop are likely to give us most of the trouble.
    - Block-by-block sequential derivation process such as the MPM/merge/skip/AMVP/affine merge/affine AMVP list derivation is another area that needs attentions.
  + Memory bandwidth impact
    - A cache model would be needed to analyze the memory bandwidth impact if a coding tool requires access of off-chip memory.
  + Area cost associated with coding tools
    - Cost associated with memory storage (e.g. line buffers, tables and etc.) is easy to estimate.
    - Logic area could be estimated by counting number of operations and memory accesses, and comparing the number with the counterpart block in an existing standard such as HEVC.
    - If a coding tool is a completely new building block (e.g. BIO), it may need to be coded in RTL and synthesized to get ballpark estimate.
    - Good trade-offs between the cost and coding efficiency are critical for a commercially viable standard as we’d like to maximize coding efficiency for a given cost budget that is acceptable to the market.
* About the AHG mandates
  + It was recommended that encoder implementation complexity be studied.
  + It was recommended that software encoder/decoder implementation complexity be studied.
  + It was generally agreed that implementation studies in those additional areas should be encouraged.

The following contributions were identified as relevant to the AHG. JVET-L0049 and JVET-0326 provide hardware analysis of post-reconstruction filters, JVET-L00334 advocates skipping transform for 2xN and Nx2 chroma blocks.

* JVET-L0049, “AHG16: An architecture study of bilateral filters”, Y. Hu, M. Zhou (Broadcom)
* JVET-L0326, “CE14: Hadamard transform domain filter (Test 3)”, S. Ikonin, V. Stepin, D. Kuryshev, J. Chen (Huawei)
* JVET-L0334, “AHG16: Transform-free coding for 2×N or N×2 chroma blocks”, K. Zhang, L. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)

It was noticed that several contributions had been identified as relevant to AHG5 (e.g. JVET-L0122, JVET-L0104) advocating reduction of worst-case memory bandwidth. Those contributions are relevant to this AHG too.

The AHG recommends the following:

* Review the input contributions
* Discuss about the needs of encoder and software codec implementation study

# Project development (2)

Contributions in this category were discussed XXday XX July XXXX–XXXX (chaired by XXX).

## Text and general standard development (1)

[JVET-L0467](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4571) Multi-component video coding: an extension for truly versatile video/image compression [A. M. Tourapis, Y. Su, K. Mammou, J. Kim, D. Singer, F. Robinet (Apple)] [late]

(The proponent suggested treating this as informative, pending parent body consideration.)

Some modern multimedia applications, and especially virtual reality applications, involve image and video captures with more than 3 components. Additional components, apart from colour information, may include, for example, depth and infrared information, while some applications may use more than 3 colour primaries to best capture or represent colour information. To accommodate such applications, this contribution proposes that the new VVC standard not be designed and limited to support only up to 3 colour components, but instead be made extensible so as to support coding of imagery with multiple colour components in an efficient manner.

It was commented that there may, in some cases, be registration error between different components.

Different sampling ratios for different components may also be applicable (e.g., a 4:1 ratio horizontally or vertically).

This was not a submission for current action. This would need parent body consideration.

## Software development (0)

See CE13 360° video area and possibly others.

## Common test conditions (X)

## Coding studies ()

# Test material (1)

[JVET-L0547](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4656) Blender Foundation/Animation Studio test sequences [F. Siddi (Blender Animation Studio), T. Roosendaal (Blender Foundation)] [late]

Discussed Thu 11 Oct 1600 (GJS).

The contribution was presented by Alexis Tourapis of Apple, who may be contacted for further information.

The Blender Foundation and the Blender Animation Studio have made several new sequences available for use in JCT-VC and JVET activities. All sequences include computer-generated content of different characteristics and using different artistic forms, and are provided in a variety of resolutions and formats. The copyright holders offer the sequences free of charge and under a copyright license claimed to be suitable for use in standardization projects.

Six test sequences were reported to be made available.

The majority of the video content used and tested by the JCT-VC and JVET groups includes natural scene sequences, whereas the majority of animated and computer generated content used by these groups cannot be considered as being very representative of the content used in practice. Therefore, six new animated/computer generated sequences are provided to these groups by the Blender Foundation and Blender Animation Studio. All sequences are several minutes long, however appropriate length, i.e. 8-12 seconds, contiguous segments can be found in all sequences for use by JCT-VC and JVET experiments.

The six sequences provided by the Blender Foundation and the Blender Animation Studio are provided in a variety of formats and resolutions. All content is provided in the RGB (BT.709) representation with sRGB transfer characteristics. Information on the different segments contained in the sequences Hero and Sintel is also provided.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Movie | Format | Transfer Characteristics | Precision | Colour Primaries | Frame rate | Resolution | Number of frames | Copyright |
| Caminandes[[1]](#footnote-2) | EXR | sRGB | Float | BT.709 | 24 fps | 1920x1080 | 3601 | Blender Foundation |
| Cosmos Laundromat | PNG | sRGB | 16bit | BT.709 | 24 fps | 2048x858 | 8572 | Blender Foundation |
| Daily Dweebs | TIFF | sRGB | 8bit | BT.709 | 24 fps | 7680x4320 | 1440 | Blender Animation Studio |
| Glass Half | PNG | sRGB | 8bit | BT.709 | 24 fps | 3840x2160 | 4633 | Blender Foundation |
| Hero | PNG | sRGB | 16bit | BT.709 | 24 fps | 2048x858 | 5674 | Blender Foundation |
| Sintel | PNG | sRGB | 16bit | BT.709 | 24 fps | 4096x1744 | 21312 | Blender Foundation |

The majority of the clips in this content include characteristics such as:

* high motion,
* challenging texture structures,
* saturated colours,
* sharp edges,
* fades and/or cross-fades
* global motion,
* camera panning,
* frequently light changes,
* high contrast/dynamic range.

The copyright license is a “Creative Commons Attribution 4.0 license”.

The frame rate is 24 fps, which is a bit low.

Appreciation was expressed.

A participant particularly expressed appreciation for having cartoon content.

It was remarked that having the same content in a variety of different formats could be desirable.

L0702 Twitch Class F test sequence

Discussed Thu 11 Oct 1615 (GJS)

A new test sequence is presented to JVET for inclusion into the Class F test set. The content is screen content (an eSports game) uncompressed in yuv 4:2:0 8 bits per sample 1080p60.

The sequence is offered free of charge and under a copyright license suitable for use in standardization projects.

A set of eSport clips were looked at in a BoG of the previous meeting on 14 July 2018 (JVET-K0541v1) and the outcome is the current contribution.

Twitch is proposing the addition of a new e-sport sequence to the Class F test set. The sequence is1080p60 YUV 4:2:0 and BT.709 colour primaries. The sequence has a wide set of characteristics including camera panning, high texture as well as sharp objects and edges.

The clips proposed is of 10 seconds length without scene changes and with substantial level of details and a characteristics.

|  |  |  |
| --- | --- | --- |
| **Sequence** | **Frame rate** | **Number of frames** |
| Twitch\_EurotruckSimulator2\_1920x1080\_60\_8bit\_420.yuv | 60 fps | 600 |

A coding experiment result was provided in the contribution.

Clarification of availability and copyright license is needed.

It was commented that we may want additional study and to not repeatedly modify the selection of test sequences at each meeting, which can disturb test results evaluations.

This was appreciated and will be further studied in an AHG.

# Core Experiments

## CE1: Partitioning (6)

Contributions in this category were discussed Thursday 4 Oct. 0900–1115 (chaired by JRO).

[JVET-L0021](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4561) CE1: Summary report on partitioning [J. Ma, F. Le Léannec, M. W. Park]

During the 11th Meeting in Ljubljana in July 2018 it was decided to have several technologies to be studied in a further CE on Partitioning. Some technologies were part of [1] or related to it. The tests were categorized in three categories:

1. Picture boundary handling
2. Split constraints
3. Separate trees

Overall results of all Sub-CEs (relative to VTM-2.0.1):

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | All Intra Main10 | | | | | Random Access Main 10 | | | | | Low delay B Main 10 | | | | |
|  | Y | U | V | EncT | DecT | Y | U | V | EncT | DecT | Y | U | V | EncT | DecT |
| SubCE1-1.1.1 | 0.00% | 0.01% | 0.02% | 99% | 98% | 0.02% | 0.08% | 0.01% | 99% | 98% | 0.03% | −0.10% | −0.24% | 98% | 98% |
| SubCE1-1.2.1 | 0.06% | 0.10% | 0.12% | 98% | 101% | 0.00% | 0.02% | 0.07% | 100% | 99% | −0.10% | −0.02% | −0.27% | 99% | 97% |
| SubCE1-1.2.2 | 0.07% | 0.09% | 0.11% | 100% | 100% | 0.12% | 0.17% | 0.18% | 100% | 100% | 0.20% | 0.10% | 0.07% | 99% | 96% |
| SubCE1-1.3.1 | 0.00% | 0.00% | 0.00% | 93% | 92% | −0.02% | −0.01% | −0.06% | 93% | 88% | −0.08% | −0.14% | −0.21% | 93% | 88% |
| SubCE2-2.1.1 | 0.00% | 0.00% | 0.00% | 100% | 100% | 0.26% | 0.35% | 0.25% | 95% | 104% | 0.30% | 0.23% | 0.20% | 98% | 101% |
| SubCE2-2.1.2 | 0.00% | 0.00% | 0.00% | 100% | 101% | 0.15% | 0.20% | 0.14% | 94% | 101% | 0.06% | 0.09% | −0.15% | 98% | 100% |
| SubCE2-2.1.3 | 0.00% | 0.00% | 0.00% | 100% | 100% | 0.35% | 0.43% | 0.27% | 87% | 101% | 0.22% | 0.21% | 0.13% | 91% | 101% |
| SubCE2-2.1.4 | 0.00% | 0.00% | 0.00% | 100% | 100% | 1.55% | 1.28% | 1.15% | 84% | 102% | 0.95% | 0.75% | 0.60% | 87% | 100% |
| SubCE3-3.1.1 | −0.01% | −0.07% | −0.06% | 111% | 111% | −0.13% | −2.32% | −1.87% | 122% | 101% | −0.03% | −0.55% | −0.63% | 115% | 102% |
| SubCE3-3.1.1-syn |  |  |  |  |  | −0.69% | −3.24% | −3.04% | 140% | 102% | −0.47% | −4.18% | −5.06% | 126% | 82% |
| SubCE3-3.1.2 | 0.02% | −0.05% | −0.05% | 89% | 90% | −0.11% | −2.25% | −1.89% | 129% | 104% | 0.00% | −0.66% | −0.89% | 110% | 97% |
| SubCE3-3.1.2-syn |  |  |  |  |  | −0.69% | −3.24% | −3.04% | 144% | 100% | −0.47% | −4.09% | −5.07% | 116% | 80% |
| SubCE3-3.2.1 | −0.01% | −0.07% | −0.06% | 85% | 92% | 0.01% | 0.01% | 0.02% | 94% | 95% | −0.04% | −0.06% | −0.08% | 82% | 89% |
| SubCE3-3.2.1-syn |  |  |  |  |  | 0.00% | 0.01% | 0.01% | 88% | 92% | 0.01% | 0.01% | 0.03% | 77% | 80% |
| SubCE3-3.2.2 | 0.02% | −0.05% | −0.05% | 85% | 91% | −0.11% | −2.24% | −1.87% | 106% | 90% | 0.04% | −0.43% | −0.78% | 92% | 89% |
| SubCE3-3.2.2-syn |  |  |  |  |  | −0.69% | −3.24% | −3.04% | 124% | 96% | −0.47% | −4.10% | −5.06% | 114% | 82% |

Sub-CE1: None of the three methods provides benefit in terms of compression (small loss for 1.1.x and 1.2.x, no change for 1.3.x)

In SubCE1-1.1.1 it is proposed to forgo the QT-split restrictions at the picture boundary and always infer a QT split if three corner points exceed the picture boundary. Further, the additional BT depth counter at the boundary is removed to ensure the BT depth does not violate the specified maximum BT depth.

Some constraints are removed, however other conditions are added (QT at corner). It is not obvious that this is a simplification.

In SubCE1-1.2.1 and SubCE1-1.2.2 a new CU type is introduced which is called *Zero-Unit (ZU)*. A ZU is a CU with width or height not being a power of 2. Hence, a ZU can only appear at the picture boundary. In current VTM a CU with non-power of 2 width or height is further split.

The proponents claim that the sub-CEs 1.2.x would be a unification. However, according to the opinion of the cross-checkers that introduction of the ZU makes the process more complicated.

In SubCE1-1.3.1 the concept of a *partial CU* is introduced. A partial CU is a CU which contains areas inside and outside the picture. However, only the area inside the picture is further coded. Moreover, only partial CUs are considered when the CU is coded as non-split and the part inside the picture boundaries has width or height non-power of 2. The concept of a partial CU is only used for in non-intra slices. Further, the residual is not coded for a partial CU and the skip flag is inferred as true for the part inside the picture.

Additional inference steps, but no benefit in compression performance in the CTC.

SubCE2 consists of four tests with the aim to reduce the VPDA size in VVC. *Virtual pipeline data units (VPDUs)* are non-overlapping MxM-luma(L)/NxN-chroma(C) units in a picture. In HEVC the VPDU size is set to maximum transform block size which is 32x32-L/16x16-C. This is compared to 128x128-L/64x64-C in VVC which leads to the request of larger VPDA sizes.

All four tests in this SubCE are designed/configured so that the following two conditions are not violated:

1. For each VPDU containing one or multiple CUs, the CUs are completely contained in the VPDU.
2. For each CU containing one or more VPDUs, the VPDUs are completely contained in the CU.

Further, the processing order of CUs shall not leave a VPDU and re-visit it later.

It is generally agreed that some restriction would be beneficial for implementation (saving memory and benefit for pipelining). All solutions end up with some loss in compression. An extreme case woudld be sub-CE 2.1.4 which always enforces a split into four 64x64 CUs but loses 1.5% on average, more for UHD sequences. Other solutions end up with less loss (0.15% minimum on average, but again more for the high res sequences). This aspect is more at the level of “fine-tuning” restrictions for the benefit of implementations, where it is however not obvious yet if the results of the CE provide already an optimum solution, there are also CE related contributions. BoG (C. Rosewarne, M. Zhou) to study the sub-CE2.x solutions and related (L0128, L0050, L0313, L0551) and suggest further action.

Sub-CE3: This SubCE studies the use of separate trees for intra in inter slices. Results are reported for the CTC and for synthetic sequences that were also provided by the proponents. The synthetic sequences were generated by copying sample values from another sequence in a checker-board pattern. The used sequences vary per GOP. It is expected that these synthetic sequences lead to higher failure rate of inter prediction. The use of separate trees is dependent on a threshold signalled in the SPS. If the number of luma samples exceed the threshold, then separate trees are available. Likewise there is a threshold in the SPS for if the number of samples is below the threshold, separate trees are not available. In the remaining case there is a flag in the bit-stream that controls if separate trees are available or not.

The following aspects are investigated:

- In intra slices, sub-CEs 3.1.2 and 3.2.2 allow disabling the separate trees at CU level;

- 3.1.1 and 3.2.1 are same as VTM in intra slices

For intra slices, the additional benefit (compared to VTM) is low in terms of compression (<=+/- 0.02%)

- For inter slices, 3.1.x use a CU-level flag that signals intra mode and if yes, sends another flag that allows separate trees below the CU level for smaller PUs/TUs

- For inter slices, 3.2.1 is signalling at CTU level that the whole CTU is intra and split separately; 3.2.2 is using another flag that switches between 3.2.1 and 3.1.x solutions.

Overall benefit is in range of 0.1% luma / approx. 2% chroma bit rate reduction in the CTC for 3.1.x and 3.2.2, no gain for 3.2.1.

Additional are brought for synthetic sequences which consist of 64x64 checkerboard patterns constructed from different sequences, which change per GOP (at every 16th picture). This gives approx. 0.7% gain, which could be asserted to be the upper possible margin of gain that would never happen in natural sequences.

During the discussion, the issue is raised that this would no longer allow separate reconstruction of luma and chroma when LM chroma is used. This requires storing 64x64 luma reconstruction blocks, which however is anyway necessary when LM chroma is used at 64x64 block level.

Generally, interesting gain particularly for chroma; however, the increase in encoder runtime (20-30%) in RA is not insignificant. Contribution JVET-L0424 reports about an encoder speedup for method 3.1.1, (run time increase 7%), however also reduces the gain to approximately half.

The gain is not significant enough to justify the increased encoder runtime and additional signalling/specification text (giving up the identity of CU/PU/TU in intra blocks).

[JVET-L0080](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4161) CE1.1.1.1: CU partitioning along picture boundaries [S.-T. Hsiang, S.-M. Lei (MediaTek)]

[JVET-L0081](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4162) CE1.2.1: Constraint for binary and ternary partitions [C.-M. Tsai, C.-W. Hsu, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0268](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4363) CE1: Zero-Unit with uniform paring process (Test 1.2.1 and Test 1.2.2) [K. Zhang, L. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-L0310](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4405) CE1-1.3.1: Partial CU for picture boundary handling [M. Xu, X. Li, S. Liu (Tencent)]

[JVET-L0424](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4523) CE1 tests 3.1.1, 3.1.2, 3.2.1, 3.2.2: Separate intra trees [K. Misra, A. Segall, F. Bossen (Sharp)]

## CE2: Adaptive loop filter (7)

Contributions in this category were discussed Thursday 4 October 0900–1130 (chaired by GJS).

[JVET-L0022](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4596) CE2: Summary report on Adaptive Loop Filter [V. Seregin, C.-Y. Chen]

This document provides a summary report of Core Experiment 2 on Adaptive Loop Filter. Initially, tests for 8 categories were described in CE, however proponents withdrew category 1 and 8. The test numbering is kept unchanged to be aligned with the CE description.

Simplification of ALF design

* Coefficients signalling
* Coefficients range restriction
* Subsampled classification
* Performance improvement of ALF
  + Fixed filters
  + Temporal filter
  + CU-level adaptivity
  + CTB filter set signalling
* Low delay encoder for ALF

*CE2.2 Filter coefficients coding*

Based on JVET-K0239, in the first test, 0-th order EG binarization is used to signal ALF coefficients. In the second test, ALF coefficient values are restricted to be in a range of [-29, 29 − 1] for non-center coefficients and in a range [0, 210-1] for center coefficient. The following tests are performed:

* CE2.2.1 Use 0-th order EG binarization for ALF coefficients
* CE2.2.2 Restrict ALF coefficients range to 10 bits

Detailed test description and results are reported in JVET-L0082.

*CE2.3 Fixed filters, temporal filters and CU-level adaptivity*

In JVET-K0371 as well as in JEM, fixed filters, temporal filters, and CU below CTB level adaptivity were proposed to use in Adaptive Loop Filter.

Fixed filters consist of total 64 7x7 filters used for luma, and a mapping is applied to select a filter for each ALF class. There are 16 choices of the mapping, and the choice (0-15) is signalled as fixed filter index. The total memory needed to store fixed filters is 1164 bytes, consisting of 64 filters x 12 coefficients x 9 bits and 16 choices x 25 classes x 6 bits for mapping table. The bit depth of coefficients in the fixed filters vary and average is 8 bits.

There are 5 sets of temporal filters, each set contains filters for all classes, and the number of classes can be up to 25. The total memory is 2350 bytes as 470 bytes per set x 5 sets. When temporal filter is applied, temporal filter index is signalled without signalling derived filters.

In VTM, ALF usage is signalled for each CTB, when CU adaptivity is enabled, the ALF usage is indicated with finer granularity below CTB level. It is applied only for luma component.

In CE2.4 and as proposed in JVET-K0382, the choice of whether fixed, temporal or signalled filter is used is indicated for each CTB, and luma and chroma ALF usage is signalled independently. In VTM, ALF for chroma can be used only if ALF is applied to luma component. Those two aspects are also tested with regular encoder setting.

The following tests are performed:

* CE2.3.1 Fixed filters
* CE2.3.2 Temporal filters
* CE2.3.3 Fixed and temporal filters
* CE2.3.4 Fixed, temporal filters and CU-level adaptivity
* CE2.3.5 Fixed, temporal filters, CU-level adaptivity and CTB based filter signalling
* CE2.3.6 Fixed, temporal filters, CU-level adaptivity, CTB based filter signalling and separate luma/chroma ALF usage indication

Detailed test description and results are reported in JVET-L0391.

*CE2.4 Low latency encoder for ALF*

In this category, low latency encoder is tested. The difference from the regular encoder is that the filter coefficients are derived from the previous picture. In JVET-K0382, the following CTB based filter signalling was proposed:

* Use the signalled set of filters derived from the previous picture
* Use temporal filter set derived from the previous pictures
* Use a set of fixed filters from 16 available sets (only for luma)
* No filter applied

In JVET-K0382, the ALF usage signalling was decoupled for luma and chroma, i.e. ALF for chroma can be applied even ALF is not used for luma component.

Low latency encoder scheme was tested for VTM anchor, then the test for proposed CTB based signalling, separate luma/chroma ALF usage, and all aspects of CE2.3, are tested with low latency encoder setting.

The following tests are performed, mirroring the CE2.3 tests:

* CE2.4.1 Fixed filters with low latency encoder
* CE2.4.2 Temporal filters with low latency encoder
* CE2.4.3 Fixed and temporal filters with low latency encoder
* CE2.4.4 Fixed, temporal filters and CU-level adaptivity with low latency encoder
* CE2.4.5 Fixed, temporal filters, CU-level adaptivity and CTB based filter signalling with low latency encoder
* CE2.4.6 Fixed, temporal filters, CU-level adaptivity, CTB based filter signalling and separate luma/chroma ALF usage indication with low latency encoder
* CE2.4.7 Low latency encoder setting for VTM anchor

Detailed test description and results are reported in JVET-L0391.

*CE 2.5 Filter coefficients restriction for bit shift operation*

ALF coefficient restriction scheme was proposed in JVET-K0215. In the test, the filter coefficients used in filtering of the luma and chroma components are divided into 2 groups. The first group contains coefficients on the edge of the filter shape and they are restricted to be from the group of {0, -4, 4, 8, -8, 16, -16, 32, -32, 64, -64, 128, -128, 256, -256} values, and the second group contains the rest of the coefficients.

The exponent values of the coefficients from the first group are signalled as the current ALF coefficients, the coefficients from the second group are signalled as in VTM.

Filter storage memory is 25 classes x 10 coefficients x 4 bits for the first category and 25 classes x (2 non-center coefficients x 11 bits and 1 center coefficient of 15 bits) for luma component, and 4 coefficient x 4 bits for the first category and 2 non-center coefficients x 11 bits and 1 center coefficient of 15 bits for chroma component. The total memory is 248 bytes.

This method is applied for both 7x7 and 5x5 filter shapes. The following tests are performed:

* CE2.5.1 Filter coefficient restriction to use bit shift operation

Detailed test description and results are reported in JVET-L0162.

*CE 2.6 Subsampled Laplacian calculation*

In JVET-K0164, it was proposed to use subsampling calculation for Laplacian based classification. 4×4 block classification based on subsampled sum-modified-Laplacian (SSML) is used. On below figures (a), (b), (c), and (d), the positions of calculating 1-D Laplacian, for gradients, gv, gh, gd1 and gd2, respectively, for a 4×4 block are shown. All of them are calculated at the subsampled positions within an 8×8 window. The rest of derivation process for class index with the calculated gradients, gv, gh, gd1 and gd2, is the same as in VTM.

The following tests are performed:

* CE2.6.1 Test subsampled positions for 4 gradients (vertical, horizontal, diagonal1, and diagonal2 gradients) are different according to each direction of gradient
* CE2.6.2 Test the unified subsampled positions D1 shown on figure (c) is used for calculation of all 4 gradients
* CE2.6.3 Test the unified subsampled positions D2 shown on figure (d) is used for calculation of all 4 gradients
* CE2.6.4 Test the unified subsampled positions H shown on figure (b) is used for calculation of all 4 gradients

Detailed test description and results are reported in JVET-L0147.

*CE2.7 Subsampled gradient calculation for highest temporal layer*

Based on JVET-K0327, in 4×4 block classification the derivative calculation of 2×2 block for those pictures at the highest temporal layer is simplified by calculating the derivative only at top-left sample position of each 2×2 block as where *dir* is the direction such as horizontal, vertical, diagonal and anti-diagonal, and is the derivative at the top-left sample position of each 2×2 luma block.

The following tests are performed:

* CE2.7.1 Subsampled gradient calculation for highest temporal layer

Detailed test description and results are reported in JVET-L0240.

|  |  |  |  |
| --- | --- | --- | --- |
| **Test** | **Description** | | |
| CE2.2.1 | Use 0-th order EG binarization for ALF coefficients | | |
| CE2.2.2 | Restrict ALF coefficients range to 10 bits | | |
| CE2.3.1 | Fixed filters | CE2.4.1 | Fixed filters with low latency encoder |
| CE2.3.2 | Temporal filters | CE2.4.2 | Temporal filters with low latency encoder |
| CE2.3.3 | Fixed and temporal filters | CE2.4.3 | Fixed and temporal filters with low latency encoder |
| CE2.3.4 | Fixed, temporal filters and CU-level adaptivity | CE2.4.4 | Fixed, temporal filters and CU-level adaptivity with low latency encoder |
| CE2.3.5 | Fixed, temporal filters, CU-level adaptivity and CTB based filter signalling | CE2.4.5 | Fixed, temporal filters, CU-level adaptivity and CTB based filter signalling with low latency encoder |
| CE2.3.6 | Fixed, temporal filters, CU-level adaptivity, CTB based filter signalling and separate luma/chroma ALF usage indication | CE2.4.6 | Fixed, temporal filters, CU-level adaptivity, CTB based filter signalling and separate luma/chroma ALF usage indication with low latency encoder |
| CE2.4.7 | Low latency encoder setting for VTM anchor | | |
| CE2.5.1 | Filter coefficient restriction to use bit shift operation | | |
| CE2.6.1 | Test subsampled positions for 4 gradients (vertical, horizontal, diagonal1, and diagonal2 gradients) are different according to each direction of gradient | | |
| CE2.6.2 | Test the unified subsampled positions D1 shown on figure (c) is used for calculation of all 4 gradients | | |
| CE2.6.3 | Test the unified subsampled positions D2 shown on figure (d) is used for calculation of all 4 gradients | | |
| CE2.6.4 | Test the unified subsampled positions H shown on figure (b) is used for calculation of all 4 gradients | | |
| CE2.7.1 | Subsampled gradient calculation for highest temporal layer | | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Test |  |  | AI |  |  |  |  | RA |  |  |  |  |  |  |  |
|  | Y | U | V | Enc | Dec | Y | U | V | Enc | Dec | Y | U | V | Enc | Dec |
| CE2.2.1 | 0.08 | 0.04 | 0.04 | 100% | 100% | 0.14 | 0.16 | 0.08 | 100% | 100% | 0.12 | -0.11 | -0.08 | 100% | 100% |
| CE2.2.2 | 0.00 | 0.00 | 0.00 | 100% | 100% | 0.00 | 0.00 | 0.00 | 100% | 101% | -0.01 | -0.04 | -0.02 | 100% | 100% |
| CE2.5.1 | 0.06 | 0.00 | 0.01 | 100% | 102% | 0.04 | 0.04 | -0.04 | 100% | 101% | -0.08 | -0.09 | -0.15 | 100% | 100% |
| CE2.6.1 | 0.06 | 0.00 | 0.00 | 100% | 100% | 0.07 | 0.04 | -0.02 | 100% | 100% | 0.04 | -0.14 | -0.16 | 100% | 100% |
| CE2.6.2 | 0.03 | 0.00 | 0.00 | 100% | 100% | 0.04 | 0.03 | -0.09 | 100% | 100% | 0.00 | -0.11 | -0.12 | 100% | 100% |
| CE2.6.3 | 0.03 | 0.00 | 0.00 | 100% | 100% | 0.04 | 0.05 | 0.00 | 100% | 100% | -0.01 | 0.11 | -0.03 | 100% | 100% |
| CE2.6.4 | 0.09 | -0.01 | -0.01 | 100% | 100% | 0.11 | 0.04 | -0.07 | 100% | 100% | 0.06 | -0.03 | -0.17 | 100% | 100% |
| CE2.7.1 | 0.00 | 0.00 | 0.00 | 100% | 99% | 0.02 | 0.00 | 0.00 | 100% | 98% | 0.00 | 0.00 | 0.00 | 100% | 99% |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Test | AI |  |  |  |  | RA |  | RA |  |  |  |  |  |  |  |
|  | Y | U | V | Enc | Dec | Y | U | V | Enc | Dec | Y | U | V | Enc | Dec |
| CE2.3.1 | -0.15 | -0.13 | -0.13 | 101% | 99% | -0.15 | -0.02 | -0.13 | 100% | 100% | -0.20 | -0.11 | -0.15 | 100% | 100% |
| CE2.3.2 | 0.00 | 0.00 | 0.00 | 100% | 100% | -0.21 | -0.18 | -0.18 | 100% | 99% | -0.39 | 0.08 | -0.25 | 100% | 100% |
| CE2.3.3 | -0.15 | -0.13 | -0.13 | 100% | 100% | -0.31 | -0.20 | -0.27 | 100% | 100% | -0.48 | 0.04 | -0.31 | 100% | 101% |
| CE2.3.4 | -0.14 | -0.13 | -0.13 | 100% | 100% | -0.36 | -0.11 | -0.20 | 100% | 99% | -0.67 | 0.05 | -0.12 | 99% | 100% |
| CE2.3.5 | -0.24 | -0.03 | 0.01 | 100% | 100% | -0.55 | 0.19 | 0.05 | 100% | 100% | -0.84 | 0.19 | 0.46 | 100% | 99% |
| CE2.3.6 | -0.23 | -0.14 | -0.15 | 101% | 100% | -0.58 | -0.09 | -0.22 | 100% | 100% | -0.86 | -0.26 | -0.04 | 99% | 100% |
| CE2.4.1 | -0.01 | -0.01 | -0.01 | 100% | 101% | 0.65 | 0.15 | 0.00 | 100% | 100% | 0.58 | -0.84 | -0.34 | 100% | 100% |
| CE2.4.2 | 0.15 | 0.11 | 0.12 | 99% | 100% | 0.55 | -0.01 | -0.12 | 100% | 100% | 0.38 | -1.02 | -0.80 | 100% | 100% |
| CE2.4.3 | -0.01 | -0.01 | -0.01 | 100% | 100% | 0.42 | -0.06 | -0.19 | 101% | 101% | 0.28 | -1.24 | -0.72 | 100% | 100% |
| CE2.4.4 | -0.01 | -0.01 | -0.01 | 100% | 100% | 0.36 | 0.00 | -0.12 | 100% | 100% | -0.04 | -0.95 | -0.60 | 101% | 100% |
| CE2.4.5 | -0.13 | 0.04 | 0.03 | 100% | 100% | -0.25 | 0.17 | 0.01 | 100% | 100% | -0.72 | -0.29 | 0.11 | 99% | 99% |
| CE2.4.6 | -0.13 | 0.04 | 0.03 | 100% | 100% | -0.23 | 0.11 | -0.13 | 100% | 100% | -0.74 | -0.52 | 0.03 | 100% | 98% |
| CE2.4.7 | 0.15 | 0.11 | 0.12 | 100% | 98% | 0.89 | 0.25 | 0.09 | 100% | 100% | 0.85 | -0.77 | -0.51 | 100% | 100% |

Anchor has CTB on/off and coefficients in slice header and chroma not filtered if luma is not filtered.

Best-performing is 2.3.6, with 0.23%/0.58%/0.86% improvement for LB luma:

* Fixed filter selection & previous picture filter selection (CTB four-way selection), CU-level on/off, chroma separate from luma

For the low-delay filtering calculation, this is 2.4.6 relative to 2.4.7: 0.28%/1.14%/1.59%.

There are up to 25 classes in the anchor; the classification is luma only.

The overall ALF gain in the anchor is about 2.5%/4.7%/3.5% for AI/RA/LB.

It was suggested to try to focus on the RA case.

It was commented that the CU-level on/off does not seem to provide enough gain to bother with (0.01% loss for AI, 0.05% for RA, 0.19% for LB).

It was suggested to focus on three options for considering the proposed ways to increase performance (ignoring chroma/luma separation for the moment):

1. No modifications for performance enhancement
2. Add temporal (0.0%/0.2%/0.4%)
3. Both temporal and fixed (with signalling at CTB level) (0.2%/0.5%/0.6% for AI/RA/LB)

After discussion of the complexity versus benefit, option 1 was selected (no change).

Regarding chroma separate from luma, there wasn’t much gain shown, although it was suggested that this could be considered a clean-up matter since it is not clear that the chroma decision needs to be coupled to the luma decision. No change was made on this either.

It was questioned whether ALF is really needed for chroma (especially if we already have chroma treated as different and secondary).

Candidate simplifications:

* EG0 instead of EGk – some loss, no significant benefit – no change.
* 10 b coeffs (instead of 11) – this seems clearly the logical thing to do, no loss. Decision (complexity reduction): Adopted (text in L0082 to be checked).
* Some coefficients are replaced with shifts (2.5.1), and some extra work is needed in the encoder because of that, some participants commented that the decoder benefit doesn’t seem substantial, the decoder becomes less straightforward if desired to take advantage of this – no change.
* Subsampling of classifiers: In the discussion, it seemed clear that we should take some action – either CE 2.6.2 (0.03%/0.04%/0.0% loss in AI/RA/LB) or subsampling both vertically and horizontally (like 2.7.1 but applied to all temporal layers, unofficially ~0.2% for RA). Decision (complexity reduction): Adopt 2.6.2 (text in L0147 to be checked).

It was commented that an especially important goal for further work on ALF would be line buffer reduction.

[JVET-L0082](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4163) CE2.2.1 and CE2.2.2: ALF coefficient coding and range constraints [Y.-C. Su, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0147](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4228) CE2: Subsampled Laplacian calculation (Test 6.1, 6.2, 6.3, and 6.4) [S.-C. Lim, J. Kang, H. Lee, J. Lee, H. Y. Kim (ETRI)]

[JVET-L0162](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4243) CE2: ALF with Multiplication Replaced by Bit-Shifting (Test 2.5.1) [S. Esenlik, B. Wang, H. Gao, A. M. Kotra, J. Chen (Huawei)]

[JVET-L0530](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4637) Crosscheck of JVET-L0162: CE2.5.1 ALF with Multiplication Replaced by Bit-Shifting [R. Vanam (Interdigital)] [late] [miss]

[JVET-L0240](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4331) CE2: Subsampled gradient calculation for highest temporal layer (Test 2.7.1) [R. Vanam, Y. He, Y. Ye (InterDigital)]

[JVET-L0391](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4488) CE2.3 and CE2.4: Fixed filters, temporal filters, CU-level control and low-latency encoder for ALF [N. Hu, H. Egilmez, V. Seregin, A. Gadde, M. Karczewicz (Qualcomm)]

## CE3: Intra prediction and mode coding (39)

Contributions in this category were discussed Thursday 4 Oct 1130–1330 and 1500-2000 (chaired by JRO).

[JVET-L0023](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4420) CE3: Summary Report on Intra Prediction and Mode Coding [G. Van der Auwera, J. Heo, A. Filippov]

This is the summary report of the third Core Experiment (CE3) [1]. The goal of CE3 is to study intra prediction tools including mode coding for the VVC standard.

The following is the list of defined sub-tests in CE3:

* CE3.1: Multiple reference line prediction (9 tests)
* CE3.2: Intra prediction modes (9 tests)
* CE3.3: Intra reference sample interpolation (7 tests)
* CE3.4: Bidirectional prediction (3 tests)
* CE3.5: Cross-component prediction and separate chroma tree (18 tests)
* CE3.6: Intra mode coding (7 tests)

The CE3 description [1] originally defined 70 tests which were reduced to 53 after tests were withdrawn. This document summarizes the objective results (BD-rates, runtimes), cross-check reports and related input contributions.

CE3.1: Multi reference line intra prediction

1) Explicit signalling of reference line

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **Ref. Lines** | **Intra Prediction Modes** | **Prediction Averaging** | **Ref. Line Index Signalling** | **Block Size Restr.** | **Top CTU Restr.** | **MTS Restr.** | **Doc. #** |
| 1.1.1 | 0,1,3 | Angular modes if index > 0 | NA | Intra mode after line index | y |  | y | JVET-L0283 (HHI, Tencent, Foxconn, ITRI) |
| 1.1.2 | 0,1,3 | Even angular modes if index > 0 | NA | Intra mode after line index | y |  | y |
| 1.1.3 | 0,1,3 | Angular modes if index > 0 | NA | Intra mode after line index (MPM only) |  |  |  |
| 1.1.4 | 0,1,3 | Angular modes if index > 0 | NA | Intra mode after line index (MPM only) |  | y |  |

2) Prediction averaging:

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **Ref. Lines** | **Intra Prediction Modes** | **Prediction Averaging** | **Ref. Line Index Signalling** | **Block Size Restr.** | **Top CTU Restr.** | **MDIS Restr.** | **Doc. #** |
| 1.2.1 | 0,1 | Angular modes | 50/50 extended/nearest | NA | y |  |  | JVET-L0431 (Sony) |
| 1.2.2 | 0,1 | Angular modes | 50/50 extended/nearest | NA | y | y |  |
| 1.2.3 idem 1.2.5 | 0,1 | Angular modes | 25/75 extended/nearest | NA | y | y |  | JVET-L0150 (ETRI) |
| 1.2.4 | 0,1 | Angular modes | 25/75 extended/nearest | NA | y | y | y |
| 1.2.5 idem 1.2.3 | 0,1 | Angular modes | 25/75 extended/nearest | NA | y | y |  | JVET-L0412 (Technicolor) |

Results:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 1.1.1 | -0.61% | -0.33% | -0.36% | 125% | 99% | -0.33% | -0.17% | -0.13% | 108% | 100% |
| 1.1.2 | -0.47% | -0.22% | -0.23% | 130% | 99% | -0.26% | -0.12% | -0.09% | 108% | 100% |
| 1.1.3 | -0.46% | -0.29% | -0.24% | 102% | 98% | -0.20% | -0.01% | -0.01% | 100% | 100% |
| 1.1.4 | -0.40% | -0.23% | -0.20% | 102% | 98% | -0.18% | -0.03% | 0.02% | 100% | 99% |
| 1.2.1 | -0.29% | -0.24% | -0.19% | 107% | 104% | -0.16% | -0.12% | -0.01% | 102% | 101% |
| 1.2.2 | -0.25% | -0.21% | -0.18% | 106% | 103% | -0.14% | -0.09% | -0.01% | 103% | 101% |
| 1.2.3 | -0.18% | -0.13% | -0.10% | 105% | 103% | -0.10% | -0.05% | -0.06% | 102% | 101% |
| 1.2.4 | -0.19% | -0.16% | -0.11% | 105% | 104% | -0.11% | -0.08% | 0.00% | 102% | 101% |
| 1.2.5 | -0.18% | -0.13% | -0.10% | 105% | 103% | -0.10% | -0.05% | -0.06% | 100% | 100% |

From these results, 1.1.3 has best tradeoff performance/complexity; 1.1.4 is a modification which does not use multiple lines from CTU above. The encoder was designed to have the same number of RD checks as the VTM.

Averaging is always done, whereas the explicit signalling allows using or not using multiple lines.

Explicit signalling does not use smoothing of samples, nor PDPC, when lines 1 or 3 are used

Averaging applies smoothing to both reference lines.

1.2.2-1.2.5 have the same restriction not using multiple lines from CTU above.

As a general conclusion, 1.1.4 is the best solution in this sub-CE.

Additional results are shown with improved interpolation filters (from CE3.3), where the gain is retained, respectively more than additive.

Decision: Adopt JVET-L0283 version 1.1.4 (with line restriction from CTU above).

CE3.2:

|  |  |  |
| --- | --- | --- |
| **Test #** | **Description** | **Doc. #** |
| 2.1.1 | ‘Line-based’ intra coding mode with a restricted number of partitions per block size (with at least 16 samples per partition; ISP: intra sub-partitions tool) | JVET-L0076 (HHI) |
| 2.1.2 | Test 2.1.1 with a restriction: the resulting partitions must have a width of at least 4 samples |
| 2.2.1 | Non-linear weighted intra prediction with inverse DCT after prediction (residual added in spatial domain) + adapted MPM list | JVET-L0199 (HHI) |
| 2.2.2 | Non-linear weighted intra prediction with modified structure of the predictors (affine intra predictions, simplifications) |
| 2.3.1 | Only use DM and LM modes for 2xN or Nx2 chroma blocks | JVET-L0277 (Tencent) |
| 2.3.2 | Only use DM and LM modes for all chroma blocks |
| 2.4.1 | Enable chroma multiple direct mode signalling (MDMS) | JVET-L0420 (ITRI) |
| 2.4.2 | MDMS + fast encoder search |
| 2.5.1 | Proposed right-column and bottom-row prediction method for planar mode | JVET-L0084 (MediaTek) |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Test #** | **Description** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 2.1.1 | ‘Line-based’ intra coding mode with a restricted number of partitions per block size (with at least 16 samples per partition) | -1.01% | -0.71% | -0.69% | 148% | 103% | -0.49% | -0.49% | -0.35% | 113% | 100% |
| 2.1.2 | Test 2.1.1 with a restriction: the resulting partitions must have a width of at least 4 samples | -0.82% | -0.58% | -0.56% | 143% | 103% | -0.46% | -0.42% | -0.29% | 112% | 101% |
| 2.2.1 | Non-linear weighted intra prediction with inverse DCT after prediction (residual added in spatial domain) | -2.46% | -1.96% | -1.94% | 264% | 127% | -1.25% | -1.16% | -1.21% | 130% | 106% |
| 2.2.2 | Non-linear weighted intra prediction with modified structure of the predictors | -1.63% | -0.96% | -0.95% | 275% | 113% | -0.90% | -0.80% | -0.85% | 137% | 105% |
| 2.3.1 | Only use DM and LM modes for 2xN or Nx2 chroma blocks | 0.00% | 0.23% | 0.32% | 95% | 95% | 0.02% | 0.18% | 0.32% | 94% | 94% |
| 2.3.2 | Only use DM and LM modes for all chroma blocks | 0.08% | 1.25% | 1.46% | 91% | 95% | 0.03% | 0.81% | 0.95% | 92% | 94% |
| 2.4.1 | Enable MDMS | -0.20% | -1.09% | -1.08% | 99% | 100% | -0.02% | -0.77% | -0.84% | 100% | 100% |
| 2.4.2 | MDMS + fast encoder search | -0.20% | -0.84% | -0.84% | 97% | 100% | 0.06% | -0.69% | -0.76% | 98% | 100% |
| 2.5.1 | Proposed right-column and bottom-row prediction method for planar mode | -0.07% | -0.04% | 0.02% | 100% | 98% | -0.01% | -0.01% | 0.08% | 100% | 98% |

2.1.1/2.1.2: The approach is basically no longer line-based, but it is rather splitting an intra CU into four sub-blocks (or 2 when the CU size is 4x8 or 8x4), uses same prediction mode for all of them, and applies transform and prediction to subblocks, where the coding order is dependent on prediction direction. Interesting gain of around 1%, but encoder runtime increases by approx. 50%. Further study recommended for reduction of encoder runtime.

2.2.1 uses matrix/vector-mult., clipping and another matrix/vector mult. (approx. 60-70 mul/sample in worst case). 2 reference lines / columns are used. Predictor is trained off-line

2.2.2 is only using one matrix/vector mult., no nonlinear operation, only 1 reference line/column. Predictor is trained offline, 35 modes or 11 modes, depending on block size, also modes are trained differently for different block sizes (with symmetry for NxM and MxN). Worst case 12 mul/sample. Memory for storing the weights is huge. The gain (1.6%) is interesting, however further study is necessary to reduce the encoder runtime; also clarify if the loading of weights may be a problem in implementation pipeline.

2.3.x use only direct and LM modes for chroma (2.3.1 for narrow blocks, 2.3.2 for all blocks). 2.3.2 has large loss in chroma (almost 1.5% bitrate increase). Crosschecker reports that the encoder/decoder runtime reductions in the table above may be too optimistic, decoder should be close to 100%. It was also asked if 2.3.1 could achieve similar results by encoder-only change (not using any other modes). No action from these results.

2.4.x constructs a list of several DM candidates. Proponents are asked to provide an analysis of the number of operations for list construction (verbally reported to be around 40 comparisons). It is also mentioned that non-CE contributions exist which achieve similar performance with less operations.

2.5.1 modifies planar mode to find a better candidate for the bottom-right position. This requires 9 additional comparison operations of available boundary samples. Gain is much less (only 0.07%) than before with this method. No action.

CE3.3: Intra reference sample interpolation

|  |  |  |
| --- | --- | --- |
| **Test #** | **Description** | **Doc. #** |
| 3.1.1 | Interpolation filter selection between 4-tap cubic and 4-tap Gaussian filter based on intra prediction mode and block size (JVET-J0017) | JVET-L0130 (LGE) |
| 3.1.2 | Interpolation filter selection between 4-tap cubic and 4-tap Gaussian filter with MDIS conditions (JVET-K0064) | JVET-L0324 (Qualcomm) |
| 3.1.3 | Interpolation filter selection between 4-tap cubic and 6-tap Gaussian (convolution of [1 2 1]/4 smoothing filter and 4-tap Gaussian) with MDIS conditions (JVET-K0165) | JVET-L0151 (ETRI) |
| 3.1.4 | Harmonization of shape-, size- and mode-dependent selection of 4-tap interpolation filters (JVET-K0518) with simplified PDPC and wide-angle intra-prediction | JVET-L0275 (Huawei) |
| 3.2.1 | Bilateral reference sample filter + 4-tap cubic interpolation filter | JVET-L0179 (HHI) |
| 3.2.2 | Bilateral reference sample filter + 4-tap cubic interpolation filter + 4-tap Gaussian interpolation filter |
| 3.3.1 | Multiple 4-tap filter | JVET-L0052 (Samsung) |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test #** | **Description** | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 3.1.1 | Interpolation filter selection between 4-tap cubic and 4-tap Gaussian filter based on intra prediction mode and block size (JVET-J0017) | -0.41% | -0.44% | -0.42% | 101% | 101% | -0.18% | -0.11% | -0.07% | 100% | 100% |
| 3.1.2 | Interpolation filter selection between 4-tap cubic and 4-tap Gaussian filter with MDIS conditions (JVET-K0064) | -0.46% | -0.58% | -0.61% | 103% | 102% | -0.19% | -0.14% | -0.13% | 103% | 103% |
| 3.1.3 | Interpolation filter selection between 4-tap cubic and 6-tap Gaussian (convolution of [1 2 1]/4 smoothing filter and 4-tap Gaussian) with MDIS conditions (JVET-K0165) | -0.44% | -0.61% | -0.70% | 103% | 101% | -0.18% | -0.47% | -0.47% | 101% | 100% |
| 3.1.4 | Harmonization of shape-, size- and mode-dependent selection of 4-tap interpolation filters (JVET-K0518) with simplified PDPC and wide-angle intra-prediction | -0.45% | -0.57% | -0.57% | 102% | 103% | -0.17% | -0.13% | -0.07% | 100% | 101% |
| 3.2.1 | Bilateral reference sample filter + 4-tap cubic interpolation filter | -0.59% | -0.68% | -0.69% | 102% | 101% | -0.26% | -0.43% | -0.45% | 100% | 100% |
| 3.2.2 | Bilateral reference sample filter + 4-tap cubic interpolation filter + 4-tap Gaussian interpolation filter | -0.60% | -0.58% | -0.61% | 104% | 102% | -0.31% | -0.51% | -0.45% | 101% | 100% |
| 3.3.1 | Multiple 4-tap filter | -0.39% | -0.59% | -0.59% | 105% | 101% | -0.16% | -0.39% | -0.28% | 101% | 100% |

Analysis of properties:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Test #** | **Luma ref. sample interpolation (angular modes excluding 2, VDIA, DIA)** | **Chroma ref. sample interpolation chroma (angular modes excluding 2, VDIA, DIA)** | **Intra luma ref. sample filtering (smoothing)** | **intraHorVerDistThres table (draft spec)** | **Compression performance (Y/U/V BD-rates) for AI configuration** |
| VTM2 | Linear (2-tap, 32-phase), 5bit | Linear (2-tap, 32-phase) | [1 2 1] / 4  Condition: VTM2 ref. sample filtering | {20, 14, 2, 0, 20, 0} | anchor |
| 3.1.1 | Cubic (4-tap, 32-phase, 9bit)  Gaussian (4-tap, 32-phase, 7bit)  Switching conditions:  (W ≤ 8 || (absAng ≤ 11 && W\*H ≤ 64) if vertical angular mode  (H ≤ 8 || (absAng ≤ 11 && W\*H ≤ 64) if horizontal angular mode | Linear (2-tap, 32-phase) | [1 2 1] / 4  Condition: VTM2 ref. sample filtering | {20, 14, 2, 0, 20, 0} | -0.41%/-0.44%/-0.42% |
| 3.1.2 | Cubic (4-tap, 32-phase, 9bit)  Gaussian (4-tap, 32-phase, 7bit)  Switching conditions: idem VTM2 ref. sample filtering | Linear (2-tap, 32-phase) | [1 2 1] / 4 for PL only (VTM2 ref. sample filtering condition) | {20, 14, 2, 0, 0, 0} | -0.46%/-0.58%/-0.61% |
| 3.1.2.1 | Cubic (4-tap, 32-phase, 7bit)  Gaussian (4-tap, 32-phase, 5bit)  Switching conditions: idem VTM2 ref. sample filtering | Linear (2-tap, 32-phase) | [1 2 1] / 4 for PL only (VTM2 ref. sample filtering condition) | {20, 14, 2, 0, 0, 0} | -0.45%/-0.60%/-0.62% |
| 3.1.2.3 | Cubic (4-tap, 16-phase, 7bit)  Gaussian (4-tap, 16-phase, 5bit)  Switching conditions: idem VTM2 ref. sample filtering | Linear (2-tap, 32-phase) | [1 2 1] / 4 for PL only (VTM2 ref. sample filtering condition) | {20, 14, 2, 0, 0, 0} | -0.41%/-0.57%/-0.57% |
| 3.1.3 | Cubic (4-tap, 32-phase, 9bit)  Gaussian (6-tap, 32-phase, 9bit)  Switching conditions: similar VTM2 ref. sample filtering excluding wide-angle and PL conditions | Idem luma | No [1 2 1] / 4  Filtered ref. sample array removed from code | {30, 14, 2, 0, 0, 0} | -0.44%/-0.61%/-0.70% |
| 3.1.4 | DCT-IF MC chroma filter (4-tap, 32-phase, 7bit, idem inter)  Gaussian (4-tap, 32-phase, 5bit)  Switching conditions: VTM2 ref. sample filtering + rectangular block conditions (incl. table with 4 elements) | Linear (2-tap, 32-phase) | [1 2 1] / 4 for PL, modes 2, VDIA, DIA (require no ref. sample interpolation) | {20,14, 2, 0, 0, 0} | -0.45%/-0.57%/-0.57% |
| 3.1.4.1 | DCT-IF MC chroma filter (4-tap, 32-phase, 7bit, idem inter)  Gaussian (4-tap, 32-phase, 5bit)  Switching conditions: VTM2 ref. sample filtering) | Linear (2-tap, 32-phase) | [1 2 1] / 4 for PL, modes 2, VDIA, DIA (require no ref. sample interpolation) | {20,14, 2, 0, 0, 0} | -0.45%/-0.54%/-0.57% |
| 3.1.4.2 | DCT-IF MC chroma filter (4-tap, 32-phase, 7bit, idem inter)  Gaussian 3.1.2.1 (4-tap, 32-phase, 5bit)  Switching conditions: VTM2 ref. sample filtering) | Linear (2-tap, 32-phase) | [1 2 1] / 4 for PL, modes 2, VDIA, DIA (require no ref. sample interpolation) | {20,14, 2, 0, 0, 0} | -0.45%/-0.56%/-0.55% |
| 3.2.1 | Cubic (4-tap, 32-phase, 9bit)  Linear (2-tap, 32-phase)  Switching condition:  W ≤ 8 if vertical angular mode  H ≤ 8 if horizontal angular mode | Idem luma | Bilateral filter  Condition: WxH ≥16x16  [1 2 1] / 4  Condition: VTM2 ref. sample filtering | {20, 14, 2, 0, 20, 0} | -0.59%/-0.68%/-0.69% |
| 3.2.2 | Cubic (4-tap, 32-phase, 9bit)  Gaussian (4-tap, 32-phase, 7bit)  Switching conditions:  W ≤ 8 if vertical angular mode  H ≤ 8 if horizontal angular mode | Idem luma | Bilateral filter  Condition: WxH ≥16x16  [1 2 1] / 4  Condition: VTM2 ref. sample filtering | {20, 14, 2, 0, 20, 0} | -0.60%/-0.58%/-0.61% |
| 3.2.1.1 | Cubic (4-tap, 32-phase, 9bit)  Linear (2-tap, 32-phase)  Switching condition:  Unfiltered ref. samples (bilateral + VTM2 ref. filtering) | Linear (2-tap, 32-phase) | Bilateral filter  Condition: WxH ≥16x16  [1 2 1] / 4  Condition: VTM2 ref. sample filtering | {20, 14, 2, 0, 0, 0} | -0.66%/-0.64%/-0.64% |
| 3.3 | Cubic pair: Cubic and Cubic-wise smoothing filter (4-tap, 32-phase, 9bit)  Gaussian pair: Gaussian and Gaussian-wise smoothing filter (4-tap, 32-phase, 9bit)  Switching conditions:  Filter decision inside the pair: (x<8 || y<8)  Pair decision:  W ≤ 16 && H ≤ 32 if vertical angular mode  H ≤ 16 && W ≤ 32 if horizontal angular mode | Idem luma | [1 2 1] / 4  Condition: VTM2 ref. sample filtering | {20, 14, 2, 0, 20, 0} | -0.39%/-0.59%/-0.59% |

Likely most gain comes from switching between lower and higher frequency cutoff.

Every proposal has some additional complexity/operations compared to VTM2.

More analysis needed about the exact complexity of the different proposals in terms of number of multiplications, comparison operations, implementability in 16 bit logic, size of LUT (for bilateral filter), potentially additional cycles in generating the prediction.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Side activity to collect this information. Additional information about complexity is given in the subsequent table (see v3 of CE3 report)**CE3 test #** | **Per block operations for directional modes** | **Interpolation per sample operations for directional modes** | | | | | | | **Filtering + interpolation?** | **If reference sample filtering + interpolation?**  **operations ([1 2 1] or bilateral)** | | | | **LUT size** | | |  |
| **Luma** | | | **Chroma** | | |  |  | **Luma** | | | |
|  | **Compares** | **read** | **×** | **+** | **read** | **×** | **+** | **clip** |  | **read** | **x** | **+** | **div** | **Cubic** | **Gaussian** | **Bilateral** | **Add. cycles** |
| VTM-2 | anchor | 2 | 2  15bit | 3 | 2 | 2  15bit | 3 |  | [1 2 1] | 3 | 0 | 3 | 0 |  |  |  |  |
| JEM-7.0 | +1 | 4 | 4  18bit | 4 | 4 | 4  18bit | 4 | cubic | [1 2 1] | 3 | 0 | 3 | 0 | 1152 bits | 1024 bits |  | 0 |
| 3.1.1 | +3 | 4 | 4  18bit | 4 | 2 | 2  15bit | 3 | cubic | [1 2 1] | 3 | 0 | 3 | 0 | 1152 bits | 1024 bits |  | 0 |
| 3.1.2 | 0 | 4 | 4  18bit | 4 | 2 | 2  15bit | 3 | cubic | no |  |  |  |  | 1152 bits | 896 bits |  | 0 |
| 3.1.2.1 | 0 | 4 | 4  16bit | 4 | 2 | 2  15bit | 3 | cubic | no |  |  |  |  | 896 bits | 640 bits |  | 0 |
| 3.1.3 | without conditions for planar and wide-angle modes, i.e., no additional comparisons with respect to VTM-2 | 4  (4-tap)  or  6  (6-tap) | 4  19bit  or  6  19bit | 4  or  6 | 4  (4-tap)  or  6  (6-tap) | 4  19bit  or  6  19bit | 4  or  6 | cubic | no |  |  |  |  | 1152 bits | 1728 bits |  | 0 |
| 3.1.4 | +5 | 4 | 4  16bit | 4 | 2 | 2  15bit | 3 | DCT IF | no |  |  |  |  | 896 bits (DCT-IF, same as MC chroma filter) | 640 bits |  | 0 |
| 3.1.4.1 | 0 | 4 | 4  16bit | 4 | 2 | 2  15bit | 3 | DCT IF | no |  |  |  |  | 896 bits  (DCT-IF, same as MC chroma filter) | 640 bits |  | 0 |
| 3.1.4.2 =  3.1.4.1 + 3.1.2.1 | 0 | 4 | 4  16bit | 4 | 2 | 2  15bit | 3 | DCT IF | no |  |  |  |  | 896 bits (DCT-IF, same as MC chroma filter) | 640 bits |  | 0 |
| 3.2.1 | +3 | 4  (4-tap)  or  2  (lin.) | 4  18bit  2  15bit | 4  3 | 4 | 4  18bit | 4 | cubic | [1 2 1]  or  Bilateral  ≥16x16  ≥64x64 | 3  7  9 | 0  12  16 | 3  19  25 | 0  1  1 | 1152 bits |  | 1208 bits | 1 |
| 3.2.1.1 | +1 | 4  (4-tap)  or  2  (lin.) | 4  18bit  2  15bit | 4  3 | 2 | 2  15bit | 3 | cubic | [1 2 1]  or  Bilateral  ≥16x16  ≥64x64 | 3  7  9 | 0  12  16 | 3  19  25 | 0  1  1 | 1152 bits |  | 1208 bits | 0 |
| 3.2.1.2 | +1 | 4  (4-tap)  or  2  (lin.) | 4  16bit  2  15bit | 4  3 | 2 | 2  15bit | 3 | cubic | [1 2 1]  or  Bilateral  ≥16x16  ≥64x64 | 3  7  9 | 0  12  16 | 3  19  25 | 0  1  1 | 896 bits |  | 774 bits | 0 |
| 3.2.2 | +3 | 4 | 4  18bit | 4 | 4 | 4  18bit | 4 | cubic | [1 2 1]  or  Bilateral  ≥16x16  ≥64x64 | 3  7  9 | 0  12  16 | 3  19  25 | 0  1  1 | 1152 bits | 1024 bits | 1208 bits | 1 |
| 3.3 | 3 + WxH (position compare can be hidden with 64bits LUT) | 4 | 4  18bit | 4 | 4 | 4  18bit | 4 | cubic | [1 2 1] | 3 | 0 | 3 | 0 | 2304 bits | 2304 bits |  | 0 |

Duplication of multiplications is not a significant complexity issue

Filter phase needs to be switched per line (load operation)

Some proposals have additional conditions e.g. depending on mode, block size etc. (once per block, not a significant issue)

Some have additional operations for bilateral or smoothing filter (also dependent on condition)

Smaller number of LUT is preferable

For interpolation, 4x6 bit need to be loaded per line in case of DCTIF

For Gaussian filter, 4x5 bit, for cubic

Bilateral filter has per sample lookup – applied to reference samples, but could be more than predicted samples in case of 4x4 block, but it is only applied for blocks with both sides >=16 (one quarter of the predicted samples)

Check solutions

3.1.2.1 cubic / Gaussian 0.45%

3.1.4.2 DCTIF / Gaussian 0.45%

3.2.1.2 cubic / bilateral+bilinear 0.65%

3.1.2.1 and 3.1.4.2 are practically identical in terms of performance and complexity

3.2.1.2 has block size condition (uncritical) and bilateral filter

The bilateral filter requires loading the LUT of 774 bits, and per filtered reference sample it has 19 adds, 13 mult. and 1 comparison, and 12 LUT operations

0.2% additional gain is not justifying the complexity

Decision: Adopt JVET-L0628 3.1.4.2 (as this filter is used somewhere else in the design)

Concern is raised that the additional results of 3.1.4.1, 3.1.2.3 and 3.1.2.4 were provided late and cannot be considered part of the CE results, in particular as it has more substantial technical changes.

CE3.4: Bidirectional prediction

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| **Test #** | **Description** | **Doc. #** |
| 4.1.1 | Linear interpolation intra prediction (LIP) | JVET-L0131 (LGE) |
| 4.2.1 | Harmonization of distance-weighted directional intra prediction (DWDIP) with simplified PDPC | JVET-L0284 (Huawei) |

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| **Test #** | **Description** | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.1.1 | Linear interpolation intra prediction (LIP) | -0.21% | -0.16% | -0.13% | 105% | 101% | -0.14% | -0.27% | -0.24% | 102% | 101% |
| 4.2.1 | Harmonization of distance-weighted directional intra prediction (DWDIP) with simplified PDPC | -0.04% | -0.04% | -0.03% | 103% | 100% | -0.08% | -0.06% | -0.06% | 101% | 101% |

4.1.1: For all intra prediction modes except planar and DC, two reference samples are generated by interpolation (without smoothing), and then averaged depending on position. PDPC is applied afterwards. Before the second prediction is generated, the bottom right sample needs to be determined, and then boundary samples at the right and bottom of the block need to be generated. This is definitely increasing the number of operations per sample. This might also cause some problems with pipelining for determining the additional boundary samples. Further study on these aspects.

4.2.1 was expected to provide more gain, which is no longer the case with VTM2. No action.

CE3.5: Cross component prediction and separate trees

1) CCLM related

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| **Test#** | **Short description** | **Doc. #** |
| 5.1.1 | Replace the LMS algorithm by a straight-line equation for CCLM mode Luma to Chroma | JVET-L0191 (Canon) |
| 5.2.7 | CCLM + line buffer restriction at top CTU boundary (1 line) | JVET-L0136 (LGE) |
| 5.5.1 | CCLM; using 1 luma line (CU) | JVET-L0339 (Huawei) |
| 5.6.2 | CCLM; using 1 luma line (CU); using simplified method from test 5.1.1 | JVET-L0340 (Huawei) |
| 5.8.1 | If above side of the current CU cross CTU boundary, then only one line of above neighbouring luma reconstructed samples is used in LM parameters derivation. | JVET-L0085 (MediaTek) |
| 5.8.2 | If above side of the current CU cross CTU boundary, then above neighbouring luma reconstructed samples are not used in LM parameters derivation. |

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|  |  | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Test#** | **Description** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 5.1.1 | Replace the LMS algorithm by a straight-line equation for CCLM mode Luma to Chroma | 0.11% | 0.48% | -0.02% | 100% | 100% | 0.08% | 0.78% | 0.19% | 101% | 97% |
| 5.2.7 | CCLM + line buffer restriction at top CTU boundary (1 line) | 0.01% | 0.01% | 0.04% | 100% | 100% | 0.01% | 0.08% | 0.02% | 100% | 100% |
| 5.5.1 | CCLM; using 1 luma line (CU) | 0.02% | 0.24% | 0.23% | 100% | 98% | 0.02% | 0.32% | 0.35% | 100% | 100% |
| 5.6.2 | CCLM; using 1 luma line (CU) from 5.5.1 with simplified method from test 5.1.1 | 0.13% | 0.77% | 0.25% | 100% | 98% | 0.08% | 1.13% | 0.44% | 99% | 99% |
| 5.8.1 | If above side of the current CU cross CTU boundary, then only one line of above neighbouring luma reconstructed samples is used in LM parameters derivation. | 0.01% | 0.01% | 0.04% | 100% | 101% | 0.01% | 0.08% | 0.02% | 100% | 102% |
| 5.8.2 | If above side of the current CU cross CTU boundary, then above neighbouring luma reconstructed samples are not used in LM parameters derivation. | 0.13% | 0.65% | 0.67% | 100% | 101% | 0.08% | 0.64% | 0.68% | 100% | 101% |

This category of experiments tries to simplify CCLM

5.8.1 and 5.2.7 are conceptually and result-wise identical

Worst case complexity is in 4x4 blocks, where CCLM requires 2N+4 mult., 7N+3 additions and 2 LUT operations. 5.1.1 replaces this by 1 mult., 3 add, 1 LUT but introduces 2N comparisons (N=12 for 4x4 blocks). Further the LUT size is increased from 64 to 512.

The loss imposed by this method seems marginal compared to the gain that CCLM provides, and operations are significantly simplified.

Decision: Adopt JVET-L0191 conditional on providing acceptable specification text. B. Bross later checked the text and confirmed it seemed OK.

5.2.7 and 5.5.1 use 3-tap filters instead of 6-tap in cases where only 1 line is used for determining the model. Complexity-wise the difference is marginal whether this simpler filter is always used or only used at the CTU boundary. The main problem to be solved is about saving a line buffer of picture width at the CTU boundary. Solution 5.2.7 comes with almost no loss.

Decision: Adopt JVET-L0136 (5.2.7) / JVET-L0085 (5.8.1) conditional on providing acceptable specification text. B. Bross later confirmed that the text (uploaded in a revision of L0136) seemed OK.

2) Cross-component prediction tools

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| **Test#** | **Short description** | **Doc. #** |
| 5.2.1 | CCLM + CCLM Cb-to-Cr + MMLM + MFLM + LM-Angular | JVET-L0251 (Qualcomm) |
| 5.2.2 | CCLM + CCLM Cb-to-Cr |
| 5.2.3 | CCLM + CCLM Cb-to-Cr + MMLM |
| 5.2.4 | CCLM + CCLM Cb-to-Cr + MMLM + MFLM |
| 5.3.1 | Multiple neighbour-based LM (MNLM): CCLM + CCLM Cb-to-Cr + MMLM (above+left) + MMLM (above) + MMLM (left) + Test 5.8.1 (1 line buffer at CTU boundary) | JVET-L0388 (Foxconn) |
| 5.4.1 | CCLM + MDLM | JVET-L0338 (Huawei) |
| 5.4.2 | CCLM + MDLM with line buffer constraint at CTU boundary |
| 5.5.2 | CCLM + MDLM, both using 1 luma line (CU) |
| 5.6.1 | CCLM + MDLM; using simplified method from test 5.1.1 | JVET-L0340 (Huawei) |
| 5.6.3 | CCLM + MDLM; both using 1 luma line (CU); both using simplified method from test 5.1.1 |
| 5.7.2 | Adaptive inter-residual prediction with fast RDO (uses LM for Cb-to-Cr or Cr-to-Cb prediction, switchable) | JVET-L0378 (KDDI) |
| 5.9.1 | Adaptive Grouping LM | JVET-L0419 (ITRI) |

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|  |  | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Test#** | **Description** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 5.2.1 | CCLM + CCLM Cb-to-Cr + MMLM + MFLM + LM-Angular | -0.59% | -6.66% | -6.02% | 111% | 106% | -0.25% | -5.49% | -5.01% | 107% | 103% |
| 5.2.2 | CCLM + CCLM Cb-to-Cr | -0.17% | -2.26% | -1.32% | 100% | 102% | -0.04% | -1.75% | -1.16% | 101% | 102% |
| 5.2.3 | CCLM + CCLM Cb-to-Cr + MMLM | -0.49% | -4.52% | -4.29% | 102% | 102% | -0.22% | -3.74% | -3.74% | 103% | 103% |
| 5.2.4 | CCLM + CCLM Cb-to-Cr + MMLM + MFLM | -0.52% | -5.50% | -4.98% | 105% | 106% | -0.23% | -4.69% | -4.29% | 104% | 103% |
| 5.3.1 | MNLM: CCLM + CCLM Cb-to-Cr + MMLM + Above-MMLM + Left-MMLM + Test 5.8.1 (1 line buffer at CTU boundary) | -0.59% | -6.30% | -6.48% | 103% | 102% | -0.30% | -5.49% | -5.82% | 105% | 103% |
| 5.4.1 | CCLM + MDLM | -0.06% | -2.71% | -3.13% | 101% | 99% | -0.03% | -2.65% | -2.84% | 100% | 99% |
| 5.4.2 | CCLM + MDLM with line buffer constraint at CTU boundary | 0.07% | -1.52% | -1.81% | 101% | 99% | 0.04% | -1.55% | -1.77% | 100% | 99% |
| 5.5.2 | CCLM + MDLM, both using 1 luma line (CU) | -0.04% | -2.62% | -2.98% | 101% | 99% | -0.02% | -2.45% | -2.69% | 101% | 101% |
| 5.6.1 | CCLM + MDLM; using simplified method from test 5.1.1 | 0.03% | -2.12% | -2.87% | 101% | 99% | 0.02% | -1.88% | -2.66% | 100% | 98% |
| 5.6.3 | CCLM + MDLM; both using 1 luma line (CU); both using simplified method from test 5.1.1 | 0.05% | -1.88% | -2.67% | 101% | 99% | 0.03% | -1.59% | -2.38% | 101% | 100% |
| 5.7.2 | Adaptive inter-residual prediction with fast RDO | -0.14% | -2.41% | -2.67% | 101% | 100% | -0.02% | -2.25% | -2.11% | 101% | 100% |
| 5.9.1 | Adaptive Grouping LM | -0.14% | -1.48% | -1.76% | 102% | 102% | -0.07% | -1.21% | -1.42% | 103% | 101% |

Additional combination results

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|  |  | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Test#** | **Description** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 5.2.3.1 | CCLM + MMLM (4 lines) | -0.33% | -2.87% | -2.72% | 101% | 100% | -0.17% | -2.55% | -2.20% | 99% | 97% |
| 5.2.3.2 | CCLM + MMLM (2 lines only) | -0.29% | -2.55% | -2.35% | 102% | 99% | -0.13% | -2.24% | -1.77% | 100% | 98% |
| 5.2.3.3 | CCLM + MMLM (2 lines only, disabled at CTU top) | -0.24% | -2.45% | -2.28% | 102% | 102% | -0.11% | -2.18% | -1.70% | 100% | 98% |
| 5.2.3.4 | CCLM + MMLM (2 lines only, 1line at CTU top) | -0.29% | -2.52% | -2.36% | 101% | 99% | -0.12% | -2.25% | -1.79% | 100% | 99% |
| 5.3.1.1 | MNLM w/o CTU boundary line buffer restriction: CCLM + CCLM Cb-to-Cr + MMLM + Above-MMLM + Left-MMLM | -0.60% | -6.33% | -6.54% | 103% | 102% | -0.30% | -5.56% | -5.90% | 103% | 102% |

Additional results:

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|  |  | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Test#** | **Description** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 5.2.3.1 | CCLM + MMLM (4 lines) | -0.33% | -2.87% | -2.72% | 101% | 100% | -0.17% | -2.55% | -2.20% | 99% | 97% |
| 5.2.3.2 | CCLM + MMLM (2 lines only) | -0.29% | -2.55% | -2.35% | 102% | 99% | -0.13% | -2.24% | -1.77% | 100% | 98% |
| 5.2.3.3 | CCLM + MMLM (2 lines only, disabled at CTU top) | -0.24% | -2.45% | -2.28% | 102% | 102% | -0.11% | -2.18% | -1.70% | 100% | 98% |
| 5.2.3.4 | CCLM + MMLM (2 lines only, 1line at CTU top) | -0.29% | -2.52% | -2.36% | 101% | 99% | -0.12% | -2.25% | -1.79% | 100% | 99% |
| 5.3.1.1 | MNLM w/o CTU boundary line buffer restriction: CCLM + CCLM Cb-to-Cr + MMLM + Above-MMLM + Left-MMLM | -0.60% | -6.33% | -6.54% | 103% | 102% | -0.30% | -5.56% | -5.90% | 103% | 102% |

MMLM: Multiple Model LM – using 2 rows, classification of luma samples (based on their average with thresholding) to use one of two models

MNLM: Multiple Neighbour LM – extends MMLM by using samples from left neighbour, above neighbour, or both

MDLM: Multi-directional LM: Uses left or top for model computation, only used with CCLM which can still use the combination of both left and top neighbours

MFLM: Multi-filter LM: Uses MMLM with multiple filters (4 different, signalled) when downsampling luma aligned with chroma positions.

About 5.7.2: This uses prediction of one from the other component in the residual domain. A linear model is used, slightly different from CCLM – only scaling, no offset. In case of combining CCLM luma to chroma with CCLM Cb-to-Cr, only one of them is used in a current prediction block. It is mentioned that this could cause implementation problems, as Cb and Cr processing can no longer be parallelized. Gain is 0.14% luma, 2.4%/2.6% in Cb/Cr. This does not justify the additional complexity and additional building blocks in chroma processing.

Using more than 2 lines does not provide much gain (comparing 5.2.3.1 vs. 5.2.3.2)

Highest gain seems to be in the range of 0.6% for luma, 6+% for chroma (but this is only possible when various of the above methods are combined)

MDLM introduces only small additional complexity at the decoder (switching the selection of reference samples). It is otherwise keeping CCLM as is, but uses different reference samples as input. Filters are identical, and the number of samples for LM computation is the same. Provides 0.06% for luma, 2.7%/3.1% for Cb/Cr. Results of 5.6.1 show that the method still has significant gain in chroma when combined with the simplified LM computation of JVET-L0191.

Decision: Adopt JVET-L0338 method 5.4.1/JVET-L0340 method 5.6.1 conditional on providing acceptable specification text. Text was later provided in a revision of L0340, and was reported to have seemed adequate to B. Bross.

MMLM (and its add-ons MNLM, MFLM) need to determine two models. Whereas the number of samples that is used to compute the models is the same in total, it cannot be foreseen how many samples fall into which class. Therefore, it is more difficult for pipeline processing than CCLM. The classification step, though it is a simple averaging criterion, also may impose some additional pipelining issues. Gain of MMLM standalone is 0.3% luma, approx. 2.5% for chroma. It is recommended to further study whether the complexity concerns are less valid in combination with the LM computation of JVET-L0191, and whether the gain would still be preserved. It should also be investigated if MMLM and CCLM can use same building blocks.

MFLM has 0.03% luma gain, chroma approx. 0.8%, on top of MMLM, but requires additional switching of filters. Not sufficient benefit.

No results to judge the benefit of MNLM, difference on top of MMLM could be similar to MDLM compared to CCLM.

CE3.6: Intra mode coding

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| **Test #** | **Description** | **Doc. #** |
| 6.1.1 | 6 MPM (5 neighbours; order of insertion is the same as in BMS 1.0) with intra mode dependent contexts for coding MPM index; truncated binary code for non-MPM; CTU-row constraint | JVET-L0250 (Qualcomm) |
| 6.2.1 | Extended number of MPM rather than 3 | JVET-L0165 (LGE) |
| 6.3.1 | Add additional intra modes in the MPM list and use truncated binarization (TB) code for signalling non-MPM modes (“reduced computational complexity” version) | JVET-L0219 (Huawei) |
| 6.3.2 | Add additional intra modes in the MPM list and use truncated binarization (TB) code for signalling non-MPM modes. (“Improved BD-Rate gain” version) | JVET-L0220 (Huawei) |
| 6.4.1 | More than 3 MPMs with bypass coded bin, non-MPM FLC | JVET-L0086 (MediaTek) |
| 6.4.2 | More than 3 MPMs with bypass coded bin, CTU-row constraint, non-MPM FLC coding |
| 6.5.1 | 6 MPM (5 neighbours; order of insertion is the same as in BMS 1.0) with intra mode independent contexts for coding MPM index; truncated binarization to code the non-MPM modes; CTU-row constraint | JVET-L0221 (Huawei, MediaTek, LGE, Qualcomm) |

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|  |  | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Test#** | **Description** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 6.1.1 | 6 MPM (5 neighbours; order of insertion is the same as in BMS 1.0) with intra mode dependent contexts for coding MPM index; truncated binary code for non-MPM; CTU-row constraint | -0.42% | -0.40% | -0.35% | 102% | 102% | -0.17% | -0.13% | -0.16% | 100% | 99% |
| 6.2.1 | Extended number of MPM rather than 3 | -0.29% | -0.24% | -0.21% | 100% | 100% | -0.11% | -0.05% | 0.01% | 100% | 100% |
| 6.3.1 | Add additional intra modes in the MPM list and use truncated binarization (TB) code for signalling non-MPM modes (“reduced computational complexity” version) | -0.31% | -0.25% | -0.24% | 100% | 99% | -0.12% | -0.11% | -0.07% | 101% | 101% |
| 6.3.2 | Add additional intra modes in the MPM list and use truncated binarization (TB) code for signalling non-MPM modes. (“Improved BD-Rate gain” version) | -0.34% | -0.28% | -0.25% | 100% | 99% | -0.13% | -0.04% | -0.03% | 101% | 101% |
| 6.4.1 | More than 3 MPMs with bypass coded bin, non-MPM FLC | -0.33% | -0.30% | -0.27% | 100% | 98% | -0.12% | -0.05% | 0.01% | 100% | 98% |
| 6.4.2 | More than 3 MPMs with bypass coded bin, CTU-row constraint, non-MPM FLC coding | -0.29% | -0.24% | -0.21% | 100% | 99% | -0.10% | -0.04% | -0.06% | 100% | 98% |
| 6.5.1 | 6 MPM (5 neighbours; order of insertion is the same as in BMS 1.0) with intra mode independent contexts for coding MPM index; truncated binarization to code the non-MPM modes; CTU-row constraint | -0.35% | -0.34% | -0.29% | 103% | 99% | -0.13% | -0.17% | -0.07% | 101% | 99% |

6.1.1 is also closest to JEM7, which has a parsing dependency. 6.5.1 is correcting that.

Additional results are provided as follows:

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| **Combined test of CE3.6** | | JVET-L0222 (Huawei, MediaTek, LGE, Qualcomm) | | | | | | | | | |
|  |  | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Test#** | **Description** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 6.1, 6.2, 6.3, 6.4, 6.5 | Combined proposal of CE3.6 | -0.32% | -0.26% | -0.24% | 101% | 99% | -0.13% | -0.09% | -0.09% | 101% | 101% |

It is noted that the combined proposal should rather be regarded as a new proposal, as it was not originally planned in the CE plan. It was not extensively studied in the CE process.

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|  |  | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Test#** | **Description** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 6.4.1.1 | More than 3 MPMs with bypass coded bin, non-MPM Truncated Binary | -0.36% | -0.31% | -0.30% | 100% | 101% | -0.14% | -0.11% | -0.08% | 100% | 101% |
| 6.4.2.1 | More than 3 MPMs with bypass coded bin, CTU-row constraint, non-MPM Truncated Binary | -0.32% | -0.26% | -0.22% | 100% | 101% | -0.13% | 0.00% | -0.01% | 100% | 101% |

Complexity analysis:

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|  | Max number of neighbours to access | Line buffer required? | Max layers of if conditions | Max number of comparison operator | Max number of logical operators | Max number of assignment operators | Max number of increments | Max number of bit operation | Parsing dependency? | Number of Context modeling for MPM coding | number of full RDO checks | Has LUT? | LUT size | Number of condition check for remaining modes | Non-MPM coding |
| VTM2 3MPM | 2 | N | 2 | 5 | 4 | 15 | 0 | 0 | N | 1 | 1 or 2 | N | - | 0 | 6-bit FLC |
| 6.1.1 | 5 | N | 4 | 33 | 11 | 35 | 6 | 0 | Y | 4 | 1 or 2 | Y | 68 | 1 | TB |
| 6.2.1a | 2 | N | 3 | 6 | 8 | 26 | 0 | 0 | N | 1 | 1 or 2 | N | - | 1 | TB |
| 6.3.1 | 2 | N | 4 | 9 | 5 | 33 | 4 | 2 | N | 0 | 1 or 2 | N | - | 1 | TB |
| 6.3.2 | 2 | N | 3 | 23 | 4 | 46 | 18 | 2 | N | 0 | 1 or 2 | Y | 68 | 1 | TB |
| 6.4.1 | 2 | Y | 3 | 8 | 6 | 27 | 4 | 3 | N | 1 | 1 or 2 | N | - | 0 | 6-bit FLC |
| 6.4.2 | 2 | N | 3 | 8 | 5 | 27 | 4 | 3 | N | 1 | 1 or 2 | N | - | 0 | 6-bit FLC |
| 6.5.1 | 5 | N | 4 | 33 | 11 | 35 | 6 | 0 | N | 4 | 1 or 2 | Y | 68 | 1 | TB |
| Combo | 2 | N | 3 | 8 | 5 | 27 | 4 | 0 | N | 1 | 1 or 2 | N | - | 1 | TB |

The gain of those methods that are not having parsing dependency is around 0.1% for RA, 0.3% for AI.

All come with some increase in complexity. Due to the fact that no parsing dependency exists, the additional operations should not be too much of a problem.

Number of context coded bins is not increased.

Even though the gain is low, increasing the number of MPMs is generally asserted to give advantage, and appears to be manageable in terms of complexity.

Solution 6.2.1 (JVET-L0165) appears to be the best complexity tradeoff from the CE, and is a straightforward extension from VTM 3 mode solution.

JVET-L0222 is claimed to provide additional benefit in terms of compression (very small), and has slightly more operations. Furthermore, it was requested to have possibility studying it in more detail.

Spec text is available for both solutions.

BoG (X. Zhao) was established to study the two proposals (including spec text) and suggest a candidate for adoption.

[JVET-L0052](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4133) CE3: Results on Multiple 4-tap filter (Test 3.3.1) [N. Choi, M. W. Park, K. Choi (Samsung)]

[JVET-L0076](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4157) CE3: Line-based intra coding mode (Tests 2.1.1 and 2.1.2) [S. De Luxán Hernández, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

[JVET-L0084](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4165) CE3.2.5: Generation of right-column and bottom-row predictors for planar mode [M. G. Sarwer, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0085](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4166) CE3.5.8: Line buffer reduction for LM chroma [C.-M. Tsai, C.-W. Hsu, C.-Y. Chen, T.-D. Chuang, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0086](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4167) CE3.6.4: Intra mode coding with 6 MPMs with bypass coding bins and non-MPMs with FLC coding [M. G. Sarwer, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0130](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4211) CE3-3.1.1: Interpolation filter selection regarding intra mode and block size [S. Yoo, J. Heo, J. Choi, L. Li, J. Lim (LGE)]

[JVET-L0131](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4212) CE3-4.1: Harmonization of Linear interpolation intra prediction (LIP) with Simplified position dependent intra prediction combination (PDPC) and wide-angle intra prediction (WAIP) [J. Heo, J. Choi, J. Choi, S. Yoo, L. Li, J. Lim (LGE)]

[JVET-L0136](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4217) CE3: CCLM with line buffer restriction (Test 5.2.7) [J. Choi, J. Heo, S. Yoo, L. Li, J. Choi, J. Lim, S. Kim (LGE)]

[JVET-L0150](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4231) CE3: Multiple reference line prediction (Test 1.2.3 and Test 1.2.4) [J. Lee, H. Lee, S.-C. Lim, J. Kang, H. Y. Kim (ETRI)]

[JVET-L0151](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4232) CE3: Intra reference sample interpolation (Test 3.1.3) [J. Lee, H. Lee, S.-C. Lim, J. Kang, H. Y. Kim (ETRI)]

[JVET-L0165](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4256) CE3-6.2.1: Extended MPM list [L. Li, J. Heo, J. Choi, J. Choi, S. Yoo, J. Lim (LGE)]

[JVET-L0179](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4270) CE3: 4-tap interpolation filter combined with bilateral reference sample filter (Tests 3.2.1 and 3.2.2) [P. Merkle, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

[JVET-L0180](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4271) Crosscheck for CE3-1.1.1 and CE3-1.1.2 [E. Mora, A. Nasrallah, M. Raulet (Ateme)]

[JVET-L0191](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4282) CE3: Cross-component linear model simplification (Test 5.1) [G. Laroche, J. Taquet, C. Gisquet, P. Onno (Canon)]

[JVET-L0199](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4290) CE3: Non-linear weighted intra prediction (tests 2.2.1 and 2.2.2) [P. Helle, J. Pfaff, M. Schäfer, R. Rischke, T. Hinz, P. Merkle, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

[JVET-L0219](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4310) CE3 6.3.1: Intra mode coding with 6 modes in MPM list and Non-MPM modes coded with truncated binarization [B. Wang, A. M. Kotra, S. Esenlik, H. Gao, J. Chen (Huawei)]

[JVET-L0220](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4311) CE3 6.3.2: Intra mode coding with 6 MPM and remapping strategy for non-MPM signalling [A. M. Kotra, B. Wang, S. Esenlik, H. Gao, J. Chen (Huawei)]

[JVET-L0221](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4312) CE3 6.5.1: 6-MPM list with Intra mode independent CABAC context [A. M. Kotra, B. Wang, S. Esenlik, H. Gao, J. Chen (Huawei), M. G. Sarwer, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek), L. Li, J. Heo, J. Choi, S. Yoo, J. Lim (LGE), A. K. Ramasubramonian, G. Van der Auwera, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-L0222](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4313) CE3 6.6.1: A simple 6-MPM list construction with truncated binary coding for non-MPM signalling [A. M. Kotra, B. Wang, S. Esenlik, H. Gao, J. Chen (Huawei), M. G. Sarwer, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek), L. Li, J. Heo, J. Choi, S. Yoo, J. Lim (LGE), A. K. Ramasubramonian, G. Van der Auwera, M. Karczewicz (Qualcomm)]

[JVET-L0250](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4344) CE3: 6 MPM with truncated binary code for non-MPM and CTU-row constraint (Test 6.1.1) [A. K. Ramasubramonian, G. Van der Auwera, T. Hsieh, N. Hu, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-L0251](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4345) CE3: Extended LM modes (Tests 5.2.1, 5.2.2, 5.2.3, and 5.2.4) [A. K. Ramasubramonian, G. Van der Auwera, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-L0275](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4366) CE3: Intra reference sample interpolation filter (Test 3.1.4) [A. Filippov, V. Rufitskiy, J. Chen (Huawei)]

[JVET-L0277](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4372) CE3: Simplifications for chroma intra coding (Test 2.3.1 and 2.3.2) [L. Zhao, X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-L0283](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4379) CE3: Multiple reference line intra prediction (Test 1.1.1, 1.1.2, 1.1.3 and 1.1.4) [B. Bross, P. Keydel, H. Schwarz, D. Marpe, T. Wiegand (HHI), L. Zhao, X. Zhao, X. Li, S. Liu (Tencent), Y.-J. Chang, H.-Y. Jiang (Foxconn), P.-H. Lin, C.-C. Lin (ITRI)]

[JVET-L0284](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4378) CE3: Distance-weighted directional intra-prediction (Tests 4.2.1 and 4.2.2) [A. Filippov, V. Rufitskiy, J. Chen (Huawei)]

[JVET-L0324](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4419) CE3: Intra reference sample interpolation filter selection using MDIS conditions (Test 3.1.2) [G. Van der Auwera, A. K. Ramasubramonian, V. Seregin, T. Hsieh, M. Karczewicz (Qualcomm)]

[JVET-L0338](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4435) CE3: Multi-directional LM (MDLM) (Test 5.4.1 and 5.4.2) [X. Ma, H. Yang, J. Chen (Huawei)]

[JVET-L0339](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4436) CE3: CCLM/MDLM coefficients derivation method using one luma line buffer (Test 5.5.1 and 5.5.2) [X. Ma, H. Yang, J. Chen (Huawei)]

[JVET-L0340](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4437) CE3: CCLM/MDLM using simplified coefficients derivation method (Test 5.6.1, 5.6.2 and 5.6.3) [X. Ma, H. Yang, J. Chen (Huawei)]

[JVET-L0378](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4475) CE3: Adaptive inter-residual prediction (CE3-5.7.2) [K. Kawamura, Y. Kidani, S. Naito (KDDI)]

[JVET-L0388](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4485) CE3: Multiple neighbour-based linear model (Test 5.3.1) [H.-Y. Jiang, H.-J. Jhu, Y.-J. Chang (Foxconn)]

[JVET-L0412](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4510) CE3: Multiple Reference Intra Prediction (tests 1.2.5) [G. Rath, F. Urban, F. Racapé (Technicolor)]

[JVET-L0419](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4518) CE3: Adaptive multiple cross-component linear model (Test 5.9.1) [S.-P. Wang, P.-H. Lin, C.-H. Yau, C.-L. Lin, C.-C. Lin (ITRI)]

[JVET-L0420](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4519) CE3: Chroma intra prediction simplification (Test 2.4.1 and 2.4.2) [C.-H. Yau, P.-H. Lin, C.-C. Lin, B.-J. Fuh, C.-L. Lin]

[JVET-L0431](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4530) CE3: Multiple Reference Line Intra Prediction (Tests 1.2.1 and 1.2.2) [S. Keating (Sony)] [late]

No need for presentation of this was identified.

[JVET-L0628](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4741) CE3: A combination of tests 3.1.2 and 3.1.4 for intra reference sample interpolation filter [A. Filippov, V. Rufitskiy, J. Chen (Huawei), G. Van der Auwera, A. K. Ramasubramonian, V. Seregin, T. Hsieh, M. Karczewicz (Qualcomm)] [late]

No need for presentation of this was identified.

[JVET-L0701](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4815) Cross-check of contribution JVET-L0628 [J. Pfaff (HHI)] [late]

[JVET-L0667](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4781) Crosscheck of JVET-L0628 (CE3: A combination of tests 3.1.2 and 3.1.4 for intra reference sample interpolation filter) [F. Racapé (Technicolor)] [late]

## CE4: Inter prediction and motion vector coding (53)

Contributions in this category were discussed Thursday 4 October 1145–1330, 1500–2100, and Friday 5 October 0900–1000 (chaired by GJS).

[JVET-L0024](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4552) CE4: Summary report on inter prediction and motion vector coding [H. Yang, S. Liu, K. Zhang]

This contribution provides a summary report of Core Experiment 4 on inter prediction and motion vector coding. CE4 comprises 8 categories:

* Affine motion compensation
* Affine merge mode
* Planar motion vector prediction
* Merge mode enhancement
* Motion vector coding
* Reference picture boundary padding
* Local illumination compensation
* Motion data storage

All techniques are implemented on top of and tested against VTM2.0.1. For each test, a comparative study along with related tests is conducted, results and complexity analysis are provided. Crosschecking reports of all tests are integrated in this document as well.

*CE4.1: Affine motion compensation*

Simplification of VTM2.0 Affine AMVP

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 4.1.1 | Cross-model inheritance for affine candidate derivation | JVET-L0363 |
| 4.1.3.a | Simplified derivation of inherited affine candidates | JVET-L0364 |
| 4.1.3.b | Simplified derivation of constructed affine candidates |
| 4.1.3.c | 4.1.3.a + 4.1.3.b |
| 4.1.4.a | Simplified inherited affine candidate with scanning order | JVET-L0141 |
| 4.1.4.b | Simplified inherited affine candidate with the reduced number of candidate |
| 4.1.4.c | Simplified constructed affine candidate |
| 4.1.4.d | 4.1.4.a + 4.1.4.c |
| 4.1.4.e | 4.1.4.b + 4.1.4.c |
| 4.1.4.g\* | 4.1.4.d + simplified AMVP padding |
| 4.1.4.h\* | 4.1.4.e + simplified AMVP padding |
| 4.1.6.a | Simplification on AMVP candidate list construction | JVET-L0271 |

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|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.1.1 | 0.01% | 0.08% | -0.05% | 100% | 100% | 0.00% | -0.08% | -0.23% | 101% | 100% |
| 4.1.3.a | 0.02% | 0.06% | -0.03% | 101% | 100% | 0.02% | -0.06% | -0.16% | 101% | 100% |
| 4.1.3.b | 0.01% | 0.03% | -0.02% | 101% | 100% | 0.01% | -0.09% | -0.16% | 101% | 100% |
| 4.1.3.c | 0.01% | 0.05% | -0.03% | 101% | 100% | 0.01% | -0.14% | -0.29% | 101% | 100% |
| 4.1.4.a | 0.02% | 0.06% | 0.02% | 100% | 100% | -0.01% | 0.03% | -0.12% | 101% | 104% |
| 4.1.4.b | 0.03% | 0.04% | -0.04% | 100% | 100% | -0.01% | 0.06% | -0.08% | 101% | 103% |
| 4.1.4.c | 0.01% | 0.03% | -0.03% | 100% | 100% | -0.01% | -0.08% | -0.29% | 101% | 104% |
| 4.1.4.d | 0.02% | 0.10% | 0.01% | 100% | 100% | -0.01% | 0.00% | -0.07% | 100% | 100% |
| 4.1.4.e | 0.03% | 0.09% | -0.02% | 100% | 100% | -0.01% | -0.14% | -0.26% | 100% | 101% |
| 4.1.4.g\* | 0.02% | 0.08% | 0.01% | 100% | 100% | 0.01% | 0.01% | -0.07% | 100% | 104% |
| 4.1.4.h\* | 0.03% | 0.08% | 0.01% | 100% | 99% | 0.02% | -0.07% | -0.08% | 100% | 103% |
| 4.1.6.a | 0.02% | 0.06% | -0.04% | 100% | 101% | 0.01% | -0.06% | -0.08% | 102% | 108% |

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| --- | --- | --- | --- | --- | --- | --- |
| **Test#** | **AMVP list size** | **Max inherited affine candidate** | **Max constructed affine candidate** | **Max candidate comparison** | **MV scaling** | **Additional buffer** |
| Anchor | 2 | 10 | 1 | 10 | 3 | 2x |
| 4.1.1 | 2 | 10 | 1 | 10 | 3 | 2x |
| 4.1.3.a | 2 | 1 | 1 | 0 | 3 | 2x |
| 4.1.3.b | 2 | 10 | 1 | 10 | 3 | 2x |
| 4.1.3.c | 2 | 1 | 1 | 0 | 3 | 2x |
| 4.1.4.a | 2 | 1 | 1 | 1 | 3 | 2x |
| 4.1.4.b | 2 | 1 | 1 | 1 | 3 | 2x |
| 4.1.4.c | 2 | 10 | 1 | 9 | 3 | 2x |
| 4.1.4.d | 2 | 1 | 1 | 0 | 3 | 2x |
| 4.1.4.e | 2 | 1 | 1 | 0 | 3 | 2x |
| 4.1.4.g\* | 2 | 1 | 1 | 0 | 1 | 2x |
| 4.1.4.h\* | 2 | 1 | 1 | 0 | 1 | 2x |
| 4.1.6.a | 2 | 1 | 1 | 0 | 1 | 2x |

Asterisks indicate differences relative to the CE plan.

Differences in runtime we discussed; it was suggested that there is no reason for any real measurable difference.

Given the similarity of test results, it was suggested to focus on the last three rows.

Eliminating the pruning and scaling were suggested as desirable.

The last row is the most consistent with the current VTM (and HEVC) design.

Decision (complexity reduction): Adopt 4.1.6.a (text in L0271 to be checked).

Line buffer reduction

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 4.1.4.f\* | 4.1.4.h (Simplified affine MVP list construction) + line buffer reduction | JVET-L0141 |
| 4.1.11.a | Line buffer reduction for affine inherited candidates, location 1 | JVET-L0045 |
| 4.1.11.b | Line buffer reduction for affine inherited candidates, location 2 |
| 4.1.12 | Simplification of affine AMVP list construction combined with line buffer reduction | JVET-L0364 |
| 4.1.13 | CTU restriction on affine inherited candidates for line buffer reduction | JVET-L0273 |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.1.4.f\* | 0.06% | 0.12% | 0.00% | 100% | 100% | 0.03% | -0.07% | -0.10% | 101% | 104% |
| 4.1.11.a | 0.09% | 0.11% | 0.06% | 101% | 99% | 0.00% | -0.09% | -0.34% | 95% | 96% |
| 4.1.11.b | 0.12% | 0.19% | 0.07% | 95% | 93% | 0.01% | 0.11% | -0.08% | 88% | 91% |
| 4.1.12 | 0.11% | 0.14% | 0.07% | 101% | 101% | 0.04% | 0.03% | -0.02% | 101% | 100% |
| 4.1.13\* | 0.05% | 0.12% | 0.01% | 97% | 96% | -0.01% | -0.14% | -0.30% | 102% | 108% |

4.1.11.b was suggested to be not worth consideration.

The cross-checker reported that 4.1.4.f has a problem since it does not actually eliminate the line buffering as implemented, since the line buffering is still used for affine merge operation.

A non-CE contribution L0322 was said to report on eliminating inheritance from above CTUs, with a reported overall lost of 0.14% (peak loss in DaylightRoad class A2 0.58%). A participant said that class A2 is critical for affine mode despite overall averages.

4.1.12 is a combination test, not a different proposal; it is the same as 4.1.11.a for the line buffering.

4.1.13\* includes some substantial differences relative to what was planned in the CE. The contributor said it is somewhat based on 4.1.11.a with some attempt to improve performance for the 6-parameter case.

Decision (complexity reduction): Adopt 4.1.11.a (pending consideration of non-CE contributions, text in JVET-L0045 to be checked).

Other tests

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 4.1.7.a | Shape dependent control points selection for affine MVP, combined with shape dependent merge candidate selection and shape dependent AMVP list ordering | JVET-L0258 |
| 4.1.7.b | Shape dependent control points selection for affine AMVP |
| 4.1.8 | Slice-level 4/6 parameters affine model switching | JVET-L0143 |
| 4.1.10 | Slice level 4/6 parameters affine model switching | JVET-L0273 |
| 4.1.14 | Bypass coding of 4/6 parameter indication flag | JVET-L0143 |
| 4.1.16 | The sub-block size for chroma components is expanded from 2×2 to 4×4. | JVET-L0265 |
| 4.1.17.a | 3(scaling)/3(rotation)/4 model switching | JVET-L0343 |
| 4.1.17.b | 3(scaling)/3(rotation)/6 model switching |
| 4.1.17.c | 3(scaling)/3(rotation)/4/6 model switching |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.1.7.a | -0.05% | 0.04% | -0.02% | 100% | 99% | -0.06% | -0.09% | -0.23% | 97% | 100% |
| 4.1.7.b | -0.02% | 0.07% | -0.04% | 100% | 100% | -0.06% | 0.02% | -0.33% | 100% | 100% |
| 4.1.8 | 0.08% | 0.01% | 0.01% | 94% | 96% | 0.06% | 0.05% | 0.01% | 96% | 94% |
| 4.1.10 | 0.08% | 0.01% | 0.01% | 95% | 101% | 0.06% | 0.05% | 0.01% | 100% | 108% |
| 4.1.14 | 0.01% | 0.04% | -0.06% | 100% | 100% | 0.04% | -0.11% | -0.30% | 101% | 103% |
| 4.1.16 | 0.02% | 0.27% | 0.26% | 99% | 97% | -0.02% | 0.19% | -0.10% | 99% | 93% |
| 4.1.17.a | 0.57% | 0.43% | 0.32% | 111% | 100% | 0.20% | 0.01% | -0.23% | 127% | 101% |
| 4.1.17.b | 0.10% | 0.09% | 0.02% | 115% | 100% | 0.11% | -0.10% | -0.14% | 133% | 101% |
| 4.1.17.c | -0.05% | -0.02% | -0.10% | 115% | 100% | 0.00% | -0.07% | -0.08% | 131% | 100% |

4.1.7 seemed like unnecessary complication or at least unnecessary changes when considering the negligible impact. No change

4.1.8 and 4.1.10 propose to add syntax at the slice level that would constrain what can be used within the slice. The motivation is somewhat to reduce encoding time. It was commented that a similar encoder-only technique could achieve an equivalent encoding time reduction with similar coding efficiency effect. No change.

4.1.14 proposes to remove one CABAC context for switching between 4 and 6 parameter models. It has a little bit of loss. It was commented that encoders that might not actually check both models, and having a context would help to remove the flag overhead by adapting to compensate for that. The complexity reduction seemed negligible. However, the proponent said that since affine mode is not used much, the CABAC adaptation might not be very useful. No change.

4.1.16 proposes to use a 4x4 subblock instead of 2x2 for chroma in merge mode. The average of the luma MVs is proposed to be used. The 2x2 problem is found in three places in the VVC design (affine, ATMVP and ordinary inter prediction with small CUs). It was commented that having chroma moving differently from luma in a region might have some subjective effect. Consideration of this was deferred to try to have a consistent solution for all places where this phenomenon occurs.

4.1.17 adds alternative 3-parameter models that could express zooming or rotation, which are a special case of the 4-parameter model. No coding gain was shown in the CTC, although it was commented that there are other test sequences outside of our CTC that show some gain for this – e.g., a pure zoom sequence. No change.

*CE4.2: Affine merge mode*

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 4.2.1 | Common base for affine merge mode | JVET-L0366 |
| 4.2.2.a | Simplify affine merge list construction by reducing pruning operation | JVET-L0368 |
| 4.2.2.b | Simplify affine merge list construction by reducing MV scaling operation |
| 4.2.2.c | Simplify affine merge list construction by reducing maximum number of candidates |
| 4.2.2.d | Reduce line buffer in affine merge mode |
| 4.2.2.e | 4.2.2.a + 4.2.2.b + 4.2.2.c |
| 4.2.2.f | 4.2.2.a + 4.2.2.b + 4.2.2.c + 4.2.2.d |
| 4.2.2.g | 4.2.2.f + 4.1.3.c |
| 4.2.2.h | 4.2.2.e + 4.4.7.a (HMVP) |
| 4.2.3.a | Adding spatial inherit affine merge candidate on VTM affine merge | JVET-L0088 |
| 4.2.3.b | Adding corner derived affine merge candidate on VTM affine merge |
| 4.2.3.c | 4.2.3.a + 4.2.3.b |
| 4.2.3.d | 4.2.3.c + reducing line buffer |
| 4.2.4.b | Additional virtual temporal candidate | JVET-L0156 |
| 4.2.5.a | Simplification of affine merge list construction | JVET-L0278 |
| 4.2.5.b | 4.2.5.a + move ATMVP to affine merge list |
| 4.2.6.a | Simplified inherited affine candidate | JVET-L0142 |
| 4.2.6.b | Simplified constructed affine candidate |
| 4.2.6.c | 4.2.6.a + 4.2.6.b |
| 4.2.6.d | 4.2.6.c + reduced candidate number for affine candidate |
| 4.2.6.e | 4.2.6.d + line buffer reduction |
| 4.2.6.f | 4.2.6.d + 4.1.4.d |
| 4.2.6.g | 4.2.6.e + 4.1.4.f |
| 4.2.8.a | 4.2.1 + move ATMVP to affine merge list | JVET-L0369 |
| 4.2.8.b | 4.2.2.e + move ATMVP to affine merge list |
| 4.2.8.c | 4.2.2.e + 4.1.6.a (Simplification on AMVP candidate list construction) |
| 4.2.8.d | 4.2.8.b + 4.1.6.a (Simplification on AMVP candidate list construction) |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **RA** |  |  |  |  | **LB** |  |  |  |  |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.2.1 | -0.75% | -0.62% | -0.78% | 107% | 107% | -0.44% | -0.40% | -0.40% | 108% | 105% |
| 4.2.2.a | -0.73% | -0.66% | -0.75% | 107% | 107% | -0.45% | -0.51% | -0.44% | 108% | 105% |
| 4.2.2.b | -0.73% | -0.59% | -0.78% | 106% | 107% | -0.36% | -0.25% | -0.41% | 107% | 104% |
| 4.2.2.c | -0.70% | -0.54% | -0.76% | 106% | 107% | -0.42% | -0.39% | -0.39% | 108% | 105% |
| 4.2.2.d | -0.65% | -0.50% | -0.69% | 107% | 106% | -0.45% | -0.29% | -0.50% | 109% | 105% |
| 4.2.2.e | -0.66% | -0.52% | -0.69% | 107% | 106% | -0.27% | -0.30% | -0.22% | 107% | 103% |
| 4.2.2.f | -0.57% | -0.46% | -0.60% | 106% | 106% | -0.25% | -0.36% | -0.33% | 106% | 103% |
| 4.2.2.g | -0.56% | -0.38% | -0.58% | 106% | 106% | -0.24% | -0.19% | -0.44% | 107% | 103% |
| 4.2.2.h-6 | -1.10% | -1.04% | -1.24% | 105% | 106% | -0.46% | -0.48% | -0.64% | 106% | 104% |
| 4.2.2.h-8 | -1.26% | -1.31% | -1.47% | 105% | 106% | -0.57% | -0.50% | -0.77% | 106% | 104% |
| 4.2.2.h-10 | -1.31% | -1.35% | -1.56% | 106% | 106% | -0.62% | -0.67% | -0.93% | 107% | 104% |
| 4.2.3.a | -0.06% | -0.06% | -0.15% | 100% | 101% | -0.13% | -0.21% | -0.31% | 100% | 101% |
| 4.2.3.b | 0.25% | 0.22% | 0.09% | 101% | 102% | -0.04% | -0.03% | -0.08% | 100% | 101% |
| 4.2.3.c | -0.28% | -0.22% | -0.33% | 102% | 107% | -0.29% | -0.23% | -0.39% | 101% | 104% |
| 4.2.3.d | -0.17% | -0.14% | -0.28% | 101% | 107% | -0.26% | -0.26% | -0.39% | 101% | 105% |
| 4.2.4.b | -0.85% | -0.69% | -0.83% | 111% | 110% | -0.50% | -0.50% | -0.42% | 113% | 113% |
| 4.2.5.a | -0.72% | -0.55% | -0.73% | 106% | 108% | -0.33% | -0.20% | -0.37% | 109% | 111% |
| 4.2.5.b | -0.76% | -0.64% | -0.76% | 104% | 109% | -0.53% | -0.53% | -0.69% | 108% | 116% |
| 4.2.6.a | -0.71% | -0.57% | -0.72% | 107% | 107% | -0.48% | -0.48% | -0.31% | 109% | 109% |
| 4.2.6.b | -0.73% | -0.59% | -0.78% | 107% | 106% | -0.36% | -0.25% | -0.41% | 108% | 108% |
| 4.2.6.c | -0.70% | -0.56% | -0.73% | 107% | 106% | -0.35% | -0.44% | -0.27% | 108% | 108% |
| 4.2.6.d | -0.64% | -0.51% | -0.61% | 106% | 106% | -0.28% | -0.30% | -0.58% | 107% | 108% |
| 4.2.6.e | -0.56% | -0.46% | -0.58% | 106% | 106% | -0.21% | -0.15% | -0.17% | 107% | 107% |
| 4.2.6.f | -0.62% | -0.49% | -0.68% | 106% | 106% | -0.26% | -0.17% | -0.35% | 107% | 108% |
| 4.2.6.g | -0.49% | -0.39% | -0.52% | 106% | 106% | -0.19% | -0.10% | -0.25% | 106% | 108% |
| 4.2.8.a | -0.76% | -0.61% | -0.80% | 106% | 109% | -0.59% | -0.34% | -0.58% | 108% | 108% |
| 4.2.8.b | -0.69% | -0.57% | -0.73% | 104% | 107% | -0.40% | -0.33% | -0.35% | 105% | 106% |
| 4.2.8.c | -0.64% | -0.53% | -0.67% | 104% | 102% | -0.25% | -0.21% | -0.49% | 105% | 101% |
| 4.2.8.d | -0.69% | -0.57% | -0.73% | 104% | 107% | -0.40% | -0.33% | -0.35% | 105% | 106% |

The “common base” is 4.2.1 and is described in L0366. In the affine merge mode of VTM-2.0.1, only the first available affine neighbour can be used to derive motion information of the affine merge mode. In this contribution, a candidate list for affine merge mode is constructed by searching valid affine neighbours and combining the neighbour motion information of each control point.

The 4.2.2.h tests are combinations with other aspects to be considered later.

Complexity analysis

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Test#** | **AMVP list size** | **Max inherited affine candidate** | **Max constructed affine candidate** | **Max candidate comparison** | **MV scaling** | **Additional buffer** |
| 4.2.1 | 5 | 5 | 10 | 50 | 30 | 2x |
| 4.2.2.a | 5 | 1 | 10 | 0 | 20 | 2x |
| 4.2.2.b | 5 | 5 | 10 | 50 | 2 | 2x |
| 4.2.2.c | 5 | 5 | 6 | 34 | 22 | 2x |
| 4.2.2.d | 5 | 5 | 10 | 50 | 28 | 1x |
| 4.2.2.e | 5 | 1 | 6 | 0 | 2 | 2x |
| 4.2.2.f | 5 | 1 | 6 | 0 | 0 | 1x |
| 4.2.2.g | / | / | / | / | / | / |
| 4.2.2.h | / | / | / | / | / | / |
| 4.2.2.h | / | / | / | / | / | / |
| 4.2.2.h | / | / | / | / | / | / |
| 4.2.3.a | 8 | 1 | 0 | 0 | 0 | 2x |
| 4.2.3.b | 8 | 0 | 2 | 0 | 2 | 2x |
| 4.2.3.c | 8 | 1 | 2 | 0 | 2 | 2x |
| 4.2.3.d | 8 | 1 | 2 | 0 | 2 | 1x |
| 4.2.4.b | 8 | 5 | 16 | 119 | 32 | 2x |
| 4.2.5.a | 5 | 1 | 10 | 0 | 2 | 2x |
| 4.2.5.b | 5 | 1 | 10 | 0 | 2 | 2x |
| 4.2.6.a | 5 | 1 | 10 | 0 | 20 | 2x |
| 4.2.6.b | 5 | 5 | 10 | 50 | 2 | 2x |
| 4.2.6.c | 5 | 1 | 10 | 0 | 2 | 2x |
| 4.2.6.d | 5 | 1 | 6 | 0 | 2 | 2x |
| 4.2.6.e | 5 | 1 | 6 | 0 | 0 | 1x |
| 4.2.6.f | / | / | / | / | / | / |
| 4.2.6.g | / | / | / | / | / | / |
| 4.2.8.a | 5 | 5 | 10 | 50 | 30 | 2x |
| 4.2.8.b | 5 | 1 | 6 | 0 | 2 | 2x |
| 4.2.8.c | / | / | / | / | / | / |
| 4.2.8.d | / | / | / | / | / | / |
| 4.2.1 | 5 | 5 | 10 | 50 | 30 | 2x |

Focusing on 4.2.2.e, 4.2.6.d, and 4.2.8.b, these have the lowest complexity. It was commented that there is some extra logic included in 4.2.8.b that is not considered in the complexity analysis above.

4.2.2.e and 4.2.6.d have approximately the same coding efficiency and are mostly similar. 4.2.2.e was suggested to be more consistent with the VTM regular merge mode and HEVC merge mode in regard to positions checked for spatial neighbours, but has some extra checking relative to 4.2.6.d.

The cross-checker of 4.2.6.d (see L0632) additionally tested a variation of the method to make it more aligned with the spatial positions used in the scheme adopted above 4.1.6.a for affine model inheritance. This was reported to have approximately the same performance, and does not have the extra checking done in 4.2.2.e.

Decision: Adopt the variation of 4.2.6.d as modified in L0632, pending text adapted from modifying model inheritance of L0368 and cross-check confirmation (approx. 0.66% benefit for RA).

(On Saturday afternoon, this was further discussed. It was commented that the decoder complexity increase may be substantially because of increased frequency of use of the mode rather than an increase in worst case complexity.)

Proposed scheme 4.2.3 puts affine candidates in the regular merge list, with a 0.28% coding efficiency benefit relative to the VTM, but not as good coding efficiency as L0632. From a complexity perspective, it was commented that separate lists are better. No change.

Proposed scheme 4.2.8 puts the ATMVP (subblock temporal merge) candidate into the affine merge list instead of in the regular merge list. This would put all sub-block-based candidates into one list and all CU-based candidates in the other list. It has a slight coding gain (0.03% in RA, 0.13% for LB). It was noted that there is also a proposal to not use ATMVP on a subblock basis, motivated by subjective considerations. There is also some study of interaction of this with subblock deblocking filtering. So the desirability of the change is coupled with the question of whether ATMVP uses subblocks or not.

Decision: Adopt 4.2.8 moving ATMVP into the affine merge list (assuming ATMVP operates on a subblock basis, pending text – no text available currently).

*CE4.3: Planar motion vector prediction*

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 4.3.1.a | PMVP with 4x4 sub-block (for block width>=16 or height>=16) | JVET-L0070 |
| 4.3.1.b\* | PMVP with 8x8 sub-block (for block width>=16 or height>=16) |
| 4.3.1.c\* | PMVP with 8x8 sub-block (for block width>=16 and height>=16) |
| 4.3.1.d\* | PMVP with adaptive 4x4/8x8 sub-block (for block width>=16 or height>=16) |
| 4.3.1.e\* | PMVP with adaptive 4x4/8x8 sub-block (for block width>=16 and height>=16) |
| 4.3.2.a | 4.3.1.a + 4.2.8.b (used as anchor) |
| 4.3.2.b | Put 4.3.1.a candidate in 4.2.8.b affine merge list |
| 4.3.3.a | MV Planar prediction | JVET-L0413 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **RA** |  |  |  |  | **LB** |  |  |  |  |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.3.1.a | -0.63% | -0.57% | -0.77% | 104% | 114% | -0.48% | -0.47% | -0.61% | 105% | 108% |
| 4.3.1.b\* | -0.53% | -0.48% | -0.62% | 103% | 103% | -0.28% | -0.28% | -0.22% | 104% | 100% |
| 4.3.1.c\* | -0.47% | -0.42% | -0.54% | 102% | 103% | -0.27% | -0.26% | -0.25% | 102% | 101% |
| 4.3.1.d\* | -0.53% | -0.48% | -0.66% | 104% | 102% | -0.43% | -0.33% | -0.50% | 105% | 100% |
| 4.3.1.e\* | -0.48% | -0.40% | -0.56% | 102% | 103% | -0.33% | -0.27% | -0.26% | 103% | 104% |
| 4.3.2.a | -0.99% | -0.88% | -1.05% | 108% | 108% | -0.53% | -0.50% | -0.42% | 111% | 106% |
| 4.3.2.b | -0.92% | -0.79% | -0.94% | 105% | 108% | -0.56% | -0.50% | -0.49% | 106% | 106% |
| 4.3.3.a | -0.18% | -0.08% | -0.15% | 106% | 99% | -0.04% | 0.07% | 0.09% | 109% | 93% |

4.3.3.a proposes adding syntax, not just modifying merge candidate construction, but has relatively little gain for this extra control syntax, so no change was made on that.

It was suggested that the subblock size should be the same for planar and affine, so the discussion focused on the 4x4 schemes.

4.3.1.a provides 0.6% gain in RA. It was noted that a decoding time increase was reported. This is likely to be because subblock modes are being used more often, not that the amount of computation is higher when a subblock mode is being used. 4.3.2.a was a combination of modified affine and planar, adding about 0.3% above the modified affine. Since that is small, no change was made, pending resolving other matters first.

On Tuesday at 1325 (GJS), it was agreed to further study 4.3.1 in a CE. A participant suggested that the planar subblock MV studies should focus on the 8x8 subblock size for ease of implementation.

*CE4.4: Merge mode enhancement*

Non-adjacent merge candidate methods

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 4.4.1.a | Spatial-temporal merge mode (non sub-block STMVP) | JVET-L0354 |
| 4.4.1.b\* | 4.4.1.a + 4.4.7.b (HMVP for merge & AMVP) |
| 4.4.2.b | Adding non-adjacent candidate by searching round 1 and 2 with virtual block size (width + i \* grid\_width \* 2, height + i \* grid\_height \* 2) | JVET-L0323 |
| 4.4.2.c | 4.4.2.b + 4.4.7.a (HMVP for merge) | JVET-L0321 |
| 4.4.2.d | 4.4.2.b + 4.4.7.b (HMVP for merge&AMVP) |
| 4.4.3 | Non-adjacent spatial candidates with reduced line buffer and reduced search points | JVET-L0175 |
| 4.4.4.a | 4.4.2.a + line buffer reduction | JVET-L0089 |
| 4.4.4.b | 4.4.4.a + reference MV position rounding |
| 4.4.5.a | Merge mode modification, 15 checked spatial positions | JVET-L0430 |
| 4.4.5.c | Merge mode modification, 10 checked spatial positions |
| 4.4.6.a | Non-adjacent merge with no additional line buffer, check 18 potential candidates | JVET-L0399 |
| 4.4.6.b | Non-adjacent merge with no additional line buffer, check 8 potential candidates |
| 4.4.6.c | 4.4.6.a + non-sub-block STMVP |
| 4.4.6.d | 4.4.6.b + non-sub-block STMVP |
| 4.4.7.a | History-based motion vector prediction for merge | JVET-L0266 |
| 4.4.7.c | History-based motion vector prediction for merge & AMVP |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **RA** |  |  |  |  | **LB** |  |  |  |  |
| **Test#** | **Merge list size** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.4.1.a | 6 | -0.44% | -0.35% | -0.53% | 100% | 101% | -0.04% | 0.21% | 0.16% | 101% | 101% |
| 4.4.1.a | 7 | -0.52% | -0.43% | -0.57% | 100% | 101% | -0.07% | 0.14% | -0.09% | 102% | 101% |
| 4.4.1.a | 8 | -0.55% | -0.48% | -0.60% | 101% | 101% | -0.13% | 0.16% | 0.18% | 102% | 102% |
| 4.4.1.b | 6 | -0.80% | -0.81% | -0.99% | 100% |  |  |  |  |  |  |
| 4.4.2.b | 6 | -0.41% | -0.41% | -0.51% | 99% | 97% | -0.26% | -0.24% | -0.23% | 97% | 96% |
| 4.4.2.b | 8 | -0.56% | -0.65% | -0.77% | 94% | 90% | -0.41% | -0.56% | -0.55% | 93% | 90% |
| 4.4.2.b | 10 | -0.62% | -0.70% | -0.84% | 95% | 90% | -0.49% | -0.56% | -0.58% | 94% | 89% |
| 4.4.2.c | 6 | -0.58% | -0.67% | -0.79% | 92% | 89% | -0.31% | -0.35% | -0.40% | 91% | 87% |
| 4.4.2.c | 8 | -0.80% | -0.94% | -1.07% | 97% | 94% | -0.53% | -0.61% | -0.50% | 95% | 93% |
| 4.4.2.c | 10 | -0.88% | -0.99% | -1.18% | 94% | 89% | -0.59% | -0.58% | -0.49% | 92% | 87% |
| 4.4.2.d | 6 | -0.72% | -0.86% | -0.97% | 99% | 103% | -0.35% | -0.30% | -0.40% | 99% | 99% |
| 4.4.2.d | 8 | -0.94% | -1.14% | -1.26% | 102% | 104% | -0.54% | -0.64% | -0.70% | 101% | 104% |
| 4.4.2.d | 10 | -1.02% | -1.21% | -1.35% | 101% | 102% | -0.66% | -0.67% | -0.62% | 101% | 99% |
| 4.4.3 | 6 | -0.19% | -0.18% | -0.31% | 99% | 99% | -0.14% | -0.08% | -0.14% | 100% | 101% |
| 4.4.3 | 10 | -0.37% | -0.41% | -0.53% | 101% | 100% | -0.30% | -0.24% | -0.43% | 102% | 100% |
| 4.4.4.a | 8 | -0.56% | -0.65% | -0.77% | 100% | 101% | -0.41% | -0.56% | -0.55% | 100% | 102% |
| 4.4.4.b | 8 | -0.47% | -0.53% | -0.62% | 100% | 101% | -0.36% | -0.39% | -0.43% | 100% | 101% |
| 4.4.5.a | 6 | -0.39% | -0.38% | -0.50% | 99% | 98% | -0.22% | -0.24% | -0.16% | 99% | 99% |
| 4.4.5.a | 8 | -0.58% | -0.61% | -0.71% | 100% | 98% | -0.37% | -0.20% | -0.60% | 100% | 99% |
| 4.4.5.a | 10 | -0.68% | -0.79% | -0.87% | 101% | 99% | -0.51% | -0.56% | -0.60% | 101% | 99% |
| 4.4.5.c | 6 | -0.33% | -0.33% | -0.43% | 100% | 98% | -0.18% | -0.25% | -0.26% | 99% | 99% |
| 4.4.5.c | 8 | -0.48% | -0.53% | -0.62% | 101% | 98% | -0.33% | -0.38% | -0.26% | 100% | 99% |
| 4.4.5.c | 10 | -0.58% | -0.64% | -0.78% | 101% | 99% | -0.44% | -0.41% | -0.44% | 101% | 99% |
| 4.4.6.a | 6 | -0.48% | -0.51% | -0.62% | 99% | 100% | -0.28% | -0.29% | -0.23% | 85% | 91% |
| 4.4.6.a | 8 | -0.66% | -0.72% | -0.82% | 96% | 102% | -0.42% | -0.35% | -0.36% | 85% | 91% |
| 4.4.6.a | 10 | -0.76% | -0.81% | -0.99% | 100% | 100% | -0.52% | -0.41% | -0.57% | 86% | 90% |
| 4.4.6.b | 6 | -0.40% | -0.41% | -0.49% | 99% | 100% | -0.23% | -0.22% | -0.28% | 85% | 91% |
| 4.4.6.b | 8 | -0.54% | -0.60% | -0.70% | 96% | 102% | -0.39% | -0.33% | -0.56% | 84% | 91% |
| 4.4.6.b | 10 | -0.61% | -0.65% | -0.80% | 100% | 100% | -0.50% | -0.43% | -0.56% | 87% | 90% |
| 4.4.6.c | 6 | -0.82% | -0.77% | -0.90% | 99% | 101% | -0.19% | 0.08% | 0.06% | 100% | 100% |
| 4.4.6.c | 8 | -1.07% | -1.00% | -1.17% | 100% | 101% | -0.41% | 0.04% | 0.02% | 100% | 99% |
| 4.4.6.c | 10 | -1.19% | -1.20% | -1.34% | 101% | 101% | -0.53% | -0.06% | -0.12% | 101% | 100% |
| 4.4.6.d | 6 | -0.76% | -0.71% | -0.85% | 99% | 101% | -0.14% | 0.11% | 0.15% | 100% | 100% |
| 4.4.6.d | 8 | -0.97% | -0.96% | -1.08% | 100% | 101% | -0.36% | 0.08% | 0.09% | 101% | 100% |
| 4.4.6.d | 10 | -1.10% | -1.08% | -1.25% | 101% | 101% | -0.46% | -0.10% | -0.10% | 101% | 100% |
| 4.4.7.a | 6 | -0.43% | -0.51% | -0.63% | 102% | 102% | -0.18% | -0.27% | -0.35% | 100% | 102% |
| 4.4.7.a | 8 | -0.59% | -0.78% | -0.88% | 102% | 102% | -0.32% | -0.32% | -0.60% | 101% | 102% |
| 4.4.7.a | 10 | -0.65% | -0.77% | -0.91% | 102% | 102% | -0.35% | -0.52% | -0.71% | 102% | 102% |
| 4.4.7.c | 6 | -0.58% | -0.72% | -0.82% | 100% | 103% | -0.23% | -0.27% | -0.21% | 100% | 98% |
| 4.4.7.c | 8 | -0.72% | -0.89% | -1.02% | 100% | 103% | -0.38% | -0.42% | -0.57% | 101% | 103% |
| 4.4.7.c | 10 | -0.78% | -0.98% | -1.12% | 101% | 103% | -0.39% | -0.53% | -0.64% | 101% | 102% |

The complexity analysis was incomplete and the parts that were available for that were not generally agreed among the participants.

At the previous meeting there had been a suggestion to have a constraint on the maximum amount of pruning.

It was suggested that:

* Average candidate (6 extra candidates, simpler computation of those, 0.40-0.61% in RA) and PU-based STMVP (1 extra candidate but more difficult to compute, involving multiplication, 0.44-0.55% in RA) are not additive. For the same list size, there isn’t a significant difference in the gain.
  + Without increasing the number of merge candidates 0.40 for the average method without pruning, 0.45 with pruning, 0.44 for STMVP. It was suggested to not consider pruning since this adds cycles.
  + Decision: 4.4.12.a (0.38% in RA), merge list size 6 (text in L0090)
* History (0.43% for modified merge only or 0.58% if also used for AMVP, 54 byte FIFO table) and non-adjacent methods (0.41%) are not fully additive (0.58% for modified merge only or 0.72% if also used for AMVP, adding storage of MVs 9k bytes within CTU), all with 6 merge candidates in list, all numbers for RA case.
  + Decision: Adopt history method with merge list size 6, history applied also to AMVP (0.58% gain in RA, text in L0266).
  + Adding the non-adjacent on top of that would provide about 0.14%, which doesn’t seem like enough, further extending the merge list size to 8 would increase that to 0.22%.
* Merge offset and UMVE are not additive, but it was suggested to first discuss merge offset, then think about UMVE. This adds +/1 sample offsets to the MV value of candidate 0, suffixing the index value with the offset value. There are variations with 4, 8, and 16 extra candidates, with 0.45%, 0.57%, and 0.78% gain in the RA case, respectively.
  + Pending consideration of UMVE, it was initially agreed to adopt the 16-offset version of merge offset (0.78% in RA, about 6% increase in encoding time and 2% decrease in decoding time), and pending availability of text. On Tuesday at 1320 (GJS) it was agreed to further study 4.4.8 in a CE.
* 4.4.10, 4.4.13, 4.4.14 were not showing significant gain; so no change was made for those.

*CE4.5: Motion vector coding*

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 4.5.1.a | Symmetrical MVD mode | JVET-L0370 |
| 4.5.1.b | Symmetrical MVD combined with MVD representation in K0115 |
| 4.5.2.a | Asymmetrical BiMVP mode | JVET-L0298 |
| 4.5.2.c | Asymmetrical BiMVP mode + Symmetrical BiMVP mode |
| 4.5.3.b | 4.5.2.a + MVD compression + reconstruction | JVET-L0298 |
| 4.5.3.c | 4.5.2.c + MVD compression + reconstruction |
| 4.5.4.a | UMVE (1 Base candidate from VVC merge list ) | JVET-L0054 |
| 4.5.4.b | UMVE (2 Base candidates from VVC merge list ) |
| 4.5.4.c | UMVE (4 Base candidates from VVC merge list ) |
| 4.5.4.d\* | Encoder speed up of 4.5.4.a |
| 4.5.4.e\* | Decoder speed up of 4.5.4.a |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **RA** |  |  |  |  | **LD** |  |  |  |  |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.5.1.a | -0.58% | -0.42% | -0.44% | 104% | 99% | / | / | / | / | / |
| 4.5.1.b | -0.46% | -0.30% | -0.33% | 102% | 99% | / | / | / | / | / |
| 4.5.2.a | -0.41% | -0.49% | -0.59% | 106% | 99% | / | / | / | / | / |
| 4.5.2.c | -0.46% | -0.55% | -0.68% | 112% | 99% | / | / | / | / | / |
| 4.5.3.b | -0.47% | -0.58% | -0.75% | 114% | 99% | / | / | / | / | / |
| 4.5.3.c | -0.48% | -0.56% | -0.74% | 122% | 99% | / | / | / | / | / |
| 4.5.4.a | -0.92% | -0.89% | -0.99% | 103% | 99% | -0.21% | -0.36% | -0.14% | 103% | 98% |
| 4.5.4.b | -1.29% | -1.17% | -1.33% | 108% | 98% | -0.37% | -0.38% | -0.31% | 106% | 98% |
| 4.5.4.c | -1.35% | -1.19% | -1.34% | 116% | 98% | -0.37% | -0.31% | -0.48% | 113% | 97% |
| 4.5.4.d\* |  |  |  |  |  |  |  |  |  |  |
| 4.5.4.e\* |  |  |  |  |  |  |  |  |  |  |

For 4.5.1, one of the MVDs for bipred is generated by mirroring rather than being sent. When the mode applies to a CU the two reference indexes are implicit.

4.5.2 uses some mirroring for the MV itself. It was commented that there is an additional non-CE contribution that tested a combination of 4.5.1 and 4.5.2 with a different encoding optimization, showing larger gain.

LB test results were not provided for some cases.

4.5.3 has reduced MV precision for larger MVDs combined with mirroring.

UMVE 4.5.4 has a flag for whether a MVD is sent or not, the MV is predicted from a merge candidate (from a number of candidates that is fixed by design), then an MVD is sent that is either horizontal or vertical, and the amount of the difference is sent and the magnitude is a power of 2 (1/4 sample, 1/2, 1, 2, 4, 8, 16, 32, not bigger). POC-based scaling is applied similar to TMVP to determine the delta added to the MV predictor. For variant a, the number of candidates is 1, for variant b, it is 2, and for variant c, it is 4. The variant b was suggested to be the most sensible. L0054 has the text.

* Decision: Adopt UMVE variant b (1.29% in RA); this needs a better name – e.g., merge with MVD (MMVD)

On Tuesday 1320 (GJS), it was agreed to further test 4.5.1 with MMVD in a CE.

*CE4.6: Reference picture boundary padding*

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| **Test#** | **Description** | **Document#** |
| 4.6.2 | Intra boundary padding | JVET-L0223 |
| 4.6.3 | Combined inter/intra boundary padding |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.6.2 | -0.05% | -0.06% | -0.09% | 103% | 105% | -0.07% | -0.06% | -0.02% | 105% | 106% |
| 4.6.3 | -0.24% | -0.15% | -0.24% | 102% | 110% | -0.11% | -0.23% | -0.26% | 104% | 108% |

The reported gains were small. It was commented that if tile boundaries are picture boundaries there would be more of a gain, and that this report L0223. The padding size was 64 samples. For the inter case, the padding could be done in advance by increased memory area. For the intra case, the padding would need to be done “on the fly”.

An implementation-focused participant commented that the complexity of this is substantial.

No change taken on these aspects.

*CE4.7: Local illumination compensation*

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| **Test#** | **Description** | **Document#** |
| 4.7.1 | Non-temporal IC using above neighbour CU | JVET-L0056 |
| 4.7.2 | Non-temporal IC using left and above neighbour CU |

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|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.7.1 | -0.21% | -0.09% | -0.16% | 125% | 104% | 0.04% | 0.09% | 0.10% | 133% | 103% |
| 4.7.2 | -0.36% | -0.23% | -0.30% | 125% | 107% | -0.14% | -0.21% | -0.17% | 129% | 108% |

The proposed approach has lower complexity than what was done in the past for JEM, in terms of a pipeline issue – avoiding access to areas outside the CU.

This method has some storage requirement – to store the coefficients of two linear models per 8x8 area for the current CTU row and row above in line buffers.

An additional CE-related contribution L0203 avoids using models from the CTU row above, which would pretty much solve the line buffering problem. This was reported to actually have better performance than what was tested in the CE.

The performance in the BMS context was reported to be about the same.

It was commented that this still involves a pipelining dependency between the reconstruction of the area to the left and the current region, which does not ordinarily exist for inter regions. It was mentioned that perhaps this dependency could be confined to within the current CTU.

Another related contribution L0120 has an alternative pipelining approach.

Further study of the alternative approach in a CE was encouraged.

*CE4.8: Motion data storage*

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 4.8.1 | Motion information storage with alternative spatial candidates for each 8x8 region | JVET-L0169 |
| 4.8.2 | Motion information storage for each 16x16 region |
| 4.8.3 | Motion information storage with alternative spatial candidates for each 16x16 region |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **RA** |  |  |  |  | **LB** |  |  |  |  |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.8.1 | 0.00% | 0.04% | -0.03% | 98% | 82% | 0.02% | -0.01% | 0.05% | 99% | 99% |
| 4.8.2 | 0.29% | 0.32% | 0.27% | 100% | 99% | 0.61% | 0.74% | 0.63% | 100% | 97% |
| 4.8.3 | 0.17% | 0.18% | 0.14% | 100% | 99% | 0.45% | 0.43% | 0.42% | 99% | 98% |

The first test involves choosing alternative positions for motion data, trying to improve coding efficiency with 8x8 motion parameter storage as in the current VTM. The second and third tests are reducing the memory usage for motion data of reference pictures for temporal motion prediction. The second case is for 16x16 storage, which corresponds with the motion data storage granularity in HEVC. The third case is for the proposed method of alternative position storage with 16x16 granularity, showing some gain relative to the second case.

It was commented that the loss for LB is more substantial than would be desirable, so no change was made in response to this experiment.

[JVET-L0045](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4126) CE4: Test results of CE4.1.11 on line buffer reduction for affine mode [M. Zhou (Broadcom)]

[JVET-L0054](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4135) CE4 Ultimate motion vector expression (Test 4.5.4) [S. Jeong, M. W. Park, Y. Piao, M. Park, K. Choi (Samsung)]

[JVET-L0641](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4754) Cross-check of JVET-L0054 test d, e (CE4 Ultimate motion vector expression (Test 4.5.4)) [J. Choi, J. Lim (LGE)] [late]

[JVET-L0056](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4137) CE4: Test 4.7.1 and Test 4.7.2 - Non-Temporal Illumination Compensation [A. Tamse, M. W. Park, K. Choi (Samsung)]

[JVET-L0070](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4151) CE4.3.1: Planar Motion Vector Prediction [N. Zhang, J. Zheng, Y. Lin (HiSilicon)]

[JVET-L0071](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4152) CE4.4.11: Combined Average Merge Candidates [N. Zhang, X. Chen, Y. Lin, J. Zheng (HiSilicon)]

[JVET-L0088](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4169) CE4.2.3: Affine merge mode [Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0089](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4170) CE4.4.4: Non-adjacent merge candidates with buffer size reduction [Y.-L. Hsiao, T.-D. Chuang, C.-Y. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0090](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4171) CE4.4.12: Pairwise average candidates [Y.-L. Hsiao, T.-D. Chuang, C.-Y. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0141](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4222) CE4: Simplified affine MVP list construction (Test 4.1.4) [J. Lee, J. Nam, N. Park, H. Jang, J. Lim, S. Kim (LGE)]

[JVET-L0142](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4223) CE4: Simplification of the common base for affine merge (Test 4.2.2) [J. Lee, J. Nam, N. Park, H. Jang, J. Lim, S. Kim (LGE)]

[JVET-L0632](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4745) Crosscheck of JVET-L0142 (CE4: Simplification of the common base for affine merge (Test 4.2.6)) [H. Chen, H. Yang, J. Chen (Huawei)]

[JVET-L0680](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4794) Crosscheck of contribution JVET-L0632 on Crosscheck of JVET-L0142: Simplification of the common base for affine merge (CE4 Test 4.2.6) [Y. Zhang, W.-J. Chien (Qualcomm)] [late]

[JVET-L0143](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4224) CE4: Slice-level 4/6 parameters affine model switching (Test 4.1.8) and bypass coding of 4/6 parameter indication flag (Test 4.1.15) [J. Lee, J. Nam, N. Park, H. Jang, J. Lim, S. Kim (LGE)]

[JVET-L0156](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4237) CE4.2.4 Affine merge mode [F. Galpin, A. Robert, F. Leleannec (Technicolor)]

[JVET-L0580](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4690) Cross-check of contribution JVET-L0156 on CE4.2.4 (Affine merge mode) [H. Huang, Y. Zhang (Qualcomm)] [late]

[JVET-L0169](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4260) CE4.8.1 Temporal motion data storage reduction [H. Jang, J. Nam, S. Kim, J. Lim (LGE)]

[JVET-L0471](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4575) Cross check report for JVET-L0169: CE4.8.1 Temporal motion data storage reduction [X. Xu (Tencent)] [late]

[JVET-L0175](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4266) CE4: Extended Non-adjacent Spatial Merge Candidates (Test 4.4.3) [X. Chen, J. Zheng (HiSilicon)]

[JVET-L0176](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4267) CE4: Merge Offset Extension (Test 4.4.8) [X. Chen, J. Zheng (HiSilicon)]

[JVET-L0186](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4277) CE4: Candidate List Reordering (Test 4.4.13) [L. Xu, F. Chen, L. Wang (Hikvision)] [late]

[JVET-L0223](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4314) CE4.6: Intra and Inter/Intra Boundary Padding [J. Brandenburg, R. Skupin, H. Schwarz, D. Marpe, T. Schierl, T. Wiegand (HHI)]

[JVET-L0258](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4353) CE4.1.7: Shape dependent control point selection for affine mode [Y. He, X. Xiu, Y. Ye (InterDigital)]

[JVET-L0265](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4360) CE4: Affine Prediction with 4×4 Sub-blocks for Chroma Components (Test 4.1.16) [K. Zhang, L. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-L0266](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4361) CE4: History-based Motion Vector Prediction (Test 4.4.7) [L. Zhang, K. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-L0271](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4367) CE4.1.6: Simplification of affine AMVP candidate list construction [H. Huang, W.-J. Chien, Y. Han, Y. Zhang, M. Karczewicz (Qualcomm)]

[JVET-L0273](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4369) CE4: Test results of CE4.1.10 and CE4.1.13 [H. Huang, W.-J. Chien, Y. Han, Y. Zhang, M. Karczewicz (Qualcomm)]

[JVET-L0278](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4373) CE4.2.5: Simplification of affine merge list construction and move ATMVP to affine merge list [H. Huang, W.-J. Chien, Y. Han, M. Karczewicz (Qualcomm)]

[JVET-L0519](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4625) CE4: Cross-check of contribution JVET-L0278 on CE4.2.5 (simplification of affine merge list construction and move ATMVP to affine merge list) [F. Galpin, F. Leleannec, A. Robert (Technicolor)] [late]

[JVET-L0298](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4393) CE4: Bilinear Motion Vector Prediction (Test 4.5.2, Test 4.5.3) [B. Choi (Sharp)] [late]

[JVET-L0315](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4410) CE4 - Extension of merge and AMVP candidates for inter prediction (Test CE4.4.10) [G. Li, X. Xu, X. Li, S. Liu (Tencent)]

[JVET-L0318](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4413) CE4 - ranking based spatial merge candidate list for inter prediction (Test CE4.4.14) [G. Li, X. Xu, X. Li, S. Liu (Tencent)]

[JVET-L0321](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4416) CE4: Combined test of CE4.4.2 and CE4.4.7 [M. Gao, J. Ye, X. Li, X. Xu, S. Liu (Tencent), L. Zhang, K. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-L0323](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4418) CE4.4.2: Long distance merge candidates [M. Gao, J. Ye, X. Li, X. Xu, S. Liu (Tencent)]

[JVET-L0343](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4440) CE4: Adaptive multi parameter motion model (Test 4.1.17) [K. Kondo, T. Suzuki (Sony)]

[JVET-L0354](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4451) CE4.4.1: Spatial-temporal merge mode [T. Zhou, T. Ikai (Sharp)]

[JVET-L0363](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4460) CE4: Cross-model inheritance for affine candidate derivation (Test 4.1.1) [H. Chen, H. Yang, J. Chen (Huawei)]

[JVET-L0478](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4582) Cross-check of JVET-L0363: CE4.1.1 Cross-model inheritance for affine candidate derivation [Y. He (InterDigital)] [late] [miss]

[JVET-L0364](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4461) CE4: Simplification of affine AMVP list construction (Test 4.1.3 and 4.1.12) [H. Chen, H. Yang, J. Chen (Huawei)]

[JVET-L0366](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4463) CE4: Common base for affine merge mode (Test 4.2.1) [H. Chen, H. Yang, J. Chen (Huawei)]

[JVET-L0521](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4627) CE4: Cross-check of contribution JVET-L0366 on CE4.2.1 (Common base for affine merge mode) [F. Galpin, F. Leleannec, A. Robert (Technicolor)] [late]

[JVET-L0368](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4465) CE4: Affine merge enhancement with simplification (Test 4.2.2) [H. Chen, H. Yang, J. Chen (Huawei)]

[JVET-L0369](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4466) CE4: Separate list for sub-block merge candidates (Test 4.2.8) [H. Chen, H. Yang, J. Chen (Huawei)]

[JVET-L0370](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4467) CE4: Symmetrical MVD mode (Test 4.5.1) [H. Chen, H. Yang, J. Chen (Huawei)]

[JVET-L0554](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4663) Crosscheck of JVET-L0370 [S. Jeong (Samsung)] [late]

[JVET-L0376](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4473) Crosscheck for CE4.1.6 and CE4.1.13 [J. An (Alibaba)] [late]

[JVET-L0399](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4496) CE4.4.6: Improvement on Merge/Skip mode [Y. Han, W.-J. Chien, H. Huang, M. Karczewicz (Qualcomm)]

[JVET-L0413](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4511) CE4-3.3: MVPlanar prediction [S. Iwamura, S. Nemoto, A. Ichigaya (NHK)]

[JVET-L0430](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4529) CE4: Merge mode modification (Test 4.4.5) [T. Solovyev, J. Chen, S. Ikonin (Huawei)] [late]

[JVET-L0507](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4613) Crosscheck of CE4.4.11 [J. An (Alibaba)] [late]

[JVET-L0514](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4620) Cross check of CE4.4.12: "Pairwise average candidates" [F. Le Léannec (Technicolor)] [late]

[JVET-L0581](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4691) Crosscheck of CE4.1.14 on bypass coding of 4/6 parameter indication flag [H. Huang, Y. Zhang (Qualcomm) [late]

[JVET-L0201](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4292) AHG13 - Weighted Prediction vs Generalized Bi-prediction with Fade sequences [P. Bordes, E. François (Technicolor)]

This was discussed in Track B at 1230 on Tuesday (GJS).

This was an information contribution.

This document presents results of tools testing of Weighted Prediction (WP) and Generalized Bi-prediction (GBi) on Fade sequences generated from the common test sequences.

WP has been specially designed to compensate global illumination variation in video sequences such as Fades.

WP is only invoked using reference picture indexes and GBi has a different syntax at the CU level. At previous JVET Meeting (Ljubljana) it was suggested evaluating both tools with Fade sequences.

For that purpose, Fade sequences were generated from common test set with same fading tool as used for HEVC in JCT-VC. In the test, when using weighted prediction, each picture was given only one weight (although, in general, an encoder could also assign more than one weight per picture).

It was reported that under BMS-2.1 configurations, using WP tool (WP=1 and GBi=0), the BD rate changes (Y/Cb/Cr) relative to the BMS-2.1 anchors were:

* In RA, -12.0%/-13.1%/-12.7% and in LB -29.0%/-38.5%/-37.5% for CTC / WP tool / Fade Black sequences.
* In RA, -15.4%/-16.3%/-16.3% and in LB -29.9%/-39.0%/-38.1% for CTC / WP tool / Fade White sequences.

It is reported that under BMS-2.1 configurations, using GBi tool (WP=0 and GBi=1), the BD rate changes relative to the BMS-2.1 anchors are:

* In RA, -1.01%/-1.28%/-1.26% for CTC / GBi tool / Fade Black sequences.
* In RA, -0.88%/-1.19%/-1.23% for CTC / GBi tool / Fade White sequences.

Comparison with performance of WP in HM16.19 is also provided, with WP providing similar gains.

[Note: “Generalized biprediction” is not a good name, since this is no more generalized than the weighted biprediction supported in HEVC and AVC. The editors should choose a different one. “Bipredictive weighted averaging” was suggested.]

[JVET-L0590](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4702) Crosscheck of CE4.4.12 combined with CE4.4.7.a [J. An (Alibaba)] [late]

Does this relate to some non-CE?

## CE5: Arithmetic coding engine (12)

Contributions in this category were discussed Friday 5 Oct 0900–1050 (chaired by JRO).

[JVET-L0025](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4591) CE5: Summary report on the Arithmetic Coding Engine [H. Kirchhoffer, A. Said]

This is the summary report of Core Experiment 5 (CE5) on the Arithmetic Coding Engine. Twelve experiments have been conducted. Seven experiments in Subtest 1 (experiments CE5.1.1 – 5.1.7) addresses modifications to the probability estimation only. Four experiments in Subtest 2 (experiments CE5.2.1 – 5.2.4) addresses modifications to the coding interval subdivision only. One experiment in Subtest 3 (experiment 5.3.1) addresses the combination of Subtest 1 with changes to the coding interval subdivision. Probability estimators that employ custom window sizes achieve a coding gain relative to the CEM 1 (CEM=”CABAC engine mode”) reference configuration as specified in the CE5 description. However, it is unclear to what extent these effects are caused by suboptimal context model initialization values as discussed in JVET-L0552. Furthermore, the results show that a final rLPS design that has a maximum size equal to or less than 2048 bit is sufficient to achieve the compression efficiency.

The following table lists all tests that were performed in this CE and gives a summary of the tool by describing the differences to the CEM1 software (JVET-K1025).

Note on the naming convention of CE tests: ‘CE5.x.y.z’ means ‘CE5.x.y’ as specified in the CE5 description with configuration ‘z’ according to the following tables.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CE5.1 – Probability estimation** | | | | |
| **CE #** | **Proponent** | **Related Docs.** | **Summary of the tool (differences to CEM1)** | **Crosscheckers** |
| 5.1.1 | Sharp Labs | JVET-L0335 | Modifies the constant to (e.g., 32768 to 32767) in the probability estimate update function. | Qualcomm |
| 5.1.2 | Samsung | JVET-L0057 | Only the short window size model is updated for the first 31 bins of a context model. (Faster convergence in the beginning) | HHI |
| 5.1.3 | HHI | JVET-L0461 | Configuration 1: Counter variable size per context model is reduced from 15 +15 bit to 10 + 14 bit.  Configuration 2: Like configuration 1 but with custom window sizes. One 4 bit constant per context model specifies a pair of custom window sizes. | Samsung |
| 5.1.4 | HHI | JVET-L0462 | Configuration 1: State-based probability estimator using a transition table for the probability update and two state variables with 8 and 12 bit, respectively.  Configuration 2: Like configuration 1 but with custom window sizes. One 5 bit constant per context model specifies a pair of custom window sizes. | Qualcomm |
| 5.1.5 | HHI | JVET-L0462 | Like CE5.1.4, config. 2, but only one state variable with 12 bit is used per context model. A 3 bit constant is used for the custom window size. | Sharp Labs |
| 5.1.6 | Qualcomm | JVET-L0115 | Custom window sizes are used. One 4 bit constant per context model specifies a pair of custom window sizes. Fixed window parameters 4 and 7 are used for contexts of SIG, parity, and Gtx (x = 1, 2), so may not be stored. | HHI |
| 5.1.7 | Qualcomm | JVET-L0116 | One counter variable is used together with custom window sizes. One 3 bit variable per context model specifies the custom window sizes. Fixed window parameter 4 is used for the contexts of SIG, parity, and Gtx (x = 1, 2), so may not be stored. | HHI |
| HEVC |  |  | Uses one 7 bit state variable and a 63x6 bit transition table. |  |

There are two conceptual approaches: “linear” representation of probability (counter based, 5.1.1-5.1.3, 5.1.6-5.1.7) and “log” representation (LUT or state based, 5.1.4-5.1.5).

Another aspect is having one or two estimators.

A third aspect is customizing the learning rate (window size) per context.

The arithmetic coding engine itself is basically the same as in HEVC (9 bit precision)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CE5.2 – Coding interval subdivision** | | | | |
| **CE #** | **Proponent** | **Related Docs.** | **Summary of the tool (differences to CEM1)** | **Crosscheckers** |
| 5.2.1 | Sharp Labs | JVET-L0335 | Modify the subinterval range computation for the LPS symbol to ((r >> 5) \* (qLPS >> (b − 5)) >> 1) + 4. Table-based implementation possible (32x8x8bit). | MediaTek |
| 5.2.2 | MediaTek | JVET-L0094 | Multiplier-based interval subdivision.  Configuration 1: 6-bit by 5-bit multiplier.  Configuration 2: 6-bit by 4-bit multiplier.  Configuration 3: 5-bit by 5-bit multiplier.  Configuration 4: 5-bit by 4-bit multiplier.  Config. 1 and 2 can implemented as 32x8x8 bit LUT.  Config. 3 and 4 can implemented as 16x8x8 bit LUT. | Qualcomm |
| 5.2.3 | HHI | JVET-L0461 | Configuration 1: A LUT of size 32x8x8 bit is used.  Configuration 2: A LUT of size 16x8x8 bit is used. | Qualcomm |
| 5.2.4 | Qualcomm | JVET-L0117 | Combination of a LUT and some computation operations (including ‘bit-scan-reverse’) is used.  Configuration 1: A LUT of size 16x16x8 bit is used, and can be implemented by a 6-bit by 6-bit multiplier.  Configuration 2: A LUT of size 8x16x8 bit is used, and can be implemented by a 5-bit by 6-bit multiplier.  Configuration 3: A LUT of size 8x8x8 bit is used, and can be implemented by a 5-bit by 5-bit multiplier. | HHI |
| HEVC |  |  | Uses a 64x4x8 bit LUT. |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CE5.3 – Combinations of CE5.1 with coding interval subdivision techniques** | | | | |
| **CE #** | **Proponent** | **Related Docs.** | **Summary of the tool (differences to CEM1)** | **Crosscheckers** |
| 5.3.1 | HHI | JVET-L0462 | The probability estimator of CE5.1.4.2 is combined with a LUT-based coding interval subdivision.  Configuration 1: A LUT of size 32x8x8 bit is used.  Configuration 2: A LUT of size 16x8x8 bit is used. | Sharp Labs |

There are a number of CE related contributions, but it is asserted that none of them does major conceptual changes to the techniques investigated in CE.

**Average test results for subtest 5.1 (relative to CEM-1 and VTM-2.0.1).**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Averages for Subtest 5.1** | | **Over CEM1, VTM configuration** | | | | | **Over BMS-2.0.1, VTM configuration** | | | | |
| Y | U | V | EncT | DecT | Y | U | V | EncT | DecT |
| AI | CE5.1.1 | 0,01% | 0,01% | -0,02% | 100% | 101% |  |  |  |  |  |
| CE5.1.2 | -0,03% | -0,10% | -0,01% | 103% | 100% | -0.94% | -1.35% | -1.33% | 104% | 102% |
| CE5.1.3.1 | 0,03% | 0,32% | 0,31% | 104% | 101% | -0,89% | -0,94% | -1,00% | 106% | 103% |
| CE5.1.4.1 | 0,02% | -0,06% | -0,02% | 101% | 100% | -0,90% | -1,31% | -1,33% | 102% | 99% |
| CE5.1.3.2 (C\*) | -0,09% | 0,07% | 0,12% | 105% | 103% | -1,01% | -1,18% | -1,20% | 107% | 105% |
| CE5.1.4.2 (C\*) | -0,05% | -0,36% | -0,30% | 109% | 102% | -0,96% | -1,61% | -1,62% | 109% | 101% |
| CE5.1.6 (C\*) | -0,21% | 0,18% | -0,08% | 97% | 98% | -1.12% | -1.08% | -1.39% | 93% | 97% |
| CE5.1.5 (CS\*) | 0,11% | -0,13% | 0,04% | 107% | 101% | -0,81% | -1,38% | -1,28% | 107% | 101% |
| CE5.1.7 (CS\*) | 0,07% | 0,15% | 0,11% | 95% | 96% | -0.85% | -1.10% | -1.20% | 91% | 95% |
| RA | CE5.1.1 | 0,00% | 0,01% | -0,05% | 104% | 103% |  |  |  |  |  |
| CE5.1.2 | -0.19% | -0.15% | -0.30% | 101% | 101% | -0.70% | -0.83% | -0.78% | 102% | 101% |
| CE5.1.3.1 | -0,01% | -0,25% | -0,29% | 108% | 104% | -0,52% | -0,94% | -0,77% | 102% | 105% |
| CE5.1.4.1 | -0,07% | -0,14% | -0,11% | 101% | 100% | -0,58% | -0,82% | -0,59% | 94% | 96% |
| CE5.1.3.2 (C\*) | -0,43% | -0,37% | -0,37% | 109% | 106% | -0,94% | -1,05% | -0,85% | 103% | 106% |
| CE5.1.4.2 (C\*) | -0,35% | -0,27% | -0,47% | 114% | 109% | -0,86% | -0,95% | -0,95% | 106% | 104% |
| CE5.1.6 (C\*) | -0,42% | 0,32% | -0,26% | 107% | 98% | -0.93% | -0.37% | -0.74% | 97% | 99% |
| CE5.1.5 (CS\*) | -0,15% | -0,55% | -0,64% | 113% | 108% | -0,66% | -1,23% | -1,12% | 106% | 103% |
| CE5.1.7 (CS\*) | -0,03% | 0,73% | 0,45% | 105% | 97% | -0.54% | 0.04% | -0.04% | 95% | 99% |
| LB | CE5.1.1 | 0,02% | 0,12% | 0,08% | 115% | 110% |  |  |  |  |  |
| CE5.1.2 | -0.13% | -0.21% | -0.17% | 102% | 100% | -0.72% | -0.62% | 0.35% | 101% | 98% |
| CE5.1.3.1 | 0,13% | -0,47% | -1,27% | 110% | 104% | -0,48% | -0,84% | -0,65% | 101% | 105% |
| CE5.1.4.1 | -0,04% | 0,02% | -0,43% | 100% | 98% | -0,65% | -0,34% | 0,20% | 92% | 96% |
| CE5.1.3.2 (C\*) | -0,31% | -0,77% | -1,19% | 112% | 107% | -0,91% | -1,13% | -0,56% | 103% | 107% |
| CE5.1.4.2 (C\*) | -0,36% | -0,28% | -1,35% | 116% | 102% | -0,96% | -0,65% | -0,73% | 106% | 99% |
| CE5.1.6 (C\*) | -0,32% | 0,31% | -0,99% | 101% | 97% | -0.93% | -0.04% | -0.35% | 98% | 106% |
| CE5.1.5 (CS\*) | -0,09% | -0,83% | -1,62% | 116% | 106% | -0,70% | -1,20% | -1,00% | 106% | 103% |
| CE5.1.7 (CS\*) | -0,02% | 0,58% | 0,43% | 100% | 97% | -0.63% | 0.21% | 1.10% | 96% | 106% |

(C\*): Two states and two custom window sizes are used per context model

(CS\*): One state and one custom window size is used per context model

The overall maximum gain is around 0.9% for RA (and around 1+% for AI) when all three aspects (higher probability precision, multiple models, customized window) are used.

Question: Is it possible to assess how much gain typically comes from

- higher precision of probability estimate

- multiple probability models (gain approx. 0.2% in RA – comparing 5.1.4.2 vs. 5.1.5 - when customized window is on)

- customized window sizes (gain approx. 0.3% in RA – comparing 5.1.4.2 vs. 5.1.4.1 - when multiple probability is on)

Above estimates of gain are for a LUT based approach. It is noted that the gain of multiple probability models may be larger when a counter based method is used, 0.4% comparing 5.1.6 vs. 5.1.7. However, the number of bits for storing probabilities is larger here than the LUT based method.

Memory analysis:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| CE # | Document | RAM per Ctx | ROM per Ctx | ROM for LUTs | Total RAM + ROM (assuming 300 context models) | Comments |
|  |  |
| HEVC |  | 7 bit |  | 378 bit | 2,478 bit |  |
| CE5.1.1 | JVET-L0335 | 30 bit | - | - | 9,000 bit | Does not affect RAM per ctx. Can be combined with 5.1.2, 5.1.3.x, 5.1.6 and 5.1.7. |
| CE5.1.2 | JVET-L0057 | 35 bit | - | - | 10,500 bit | Only short window for the first 31 bins |
| CE5.1.3.1 | JVET-L0461 | 24 bit | - | - | 7,200 bit |  |
| CE5.1.3.2 | 24 bit | 4 bit | - | 8,400 bit | Custom WS |
| CE5.1.4.1 | JVET-L0462 | 20 bit | - | 256 bit | 6,256 bit |  |
| CE5.1.4.2 | 20 bit | 5 bit | 256 bit | 7,756 bit | Custom WS |
| CE5.1.5 | JVET-L0462 | 12 bit | 3 bit | 256 bit | 4,756 bit | Custom WS, One State |
| CE5.1.6 | JVET-L0115 | 30 bit | 4 bit | - | 10,200 bit | Custom WS |
| CE5.1.7 | JVET-L0116 | 15 bit | 3 bit | - | 5,400 bit | Custom WS, One State |

Considering the fact that the total memory even in worst case is less than one line buffer of a video, memory is asserted to be not a critical issue here.

Throughput (pipelining, number of cycles) could be a more critical issue. The probability estimate is probably OK, but potentially multiple context models, and customized window could cause problems. More analysis on this is needed. BoG (F. Bossen, M. Zhou) to look into this.

The following table compares the overall compression efficiency of subtests 2 and 3. All tests in CE5.2 use the probability estimator of CEM1. Only the coding interval subdivision is different for each test. Note that the table size of CEM1 is 512x64x9 bit, no multiplier

**Average test results for subtest 5.2 (relative to CEM-1).**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Averages for Subtest 5.2** | | **Over CEM1, VTM configuration** | | | | |  | Multiplier |  |
| Y | U | V | EncT | DecT | LUT size | size | Comments |
| AI | CE5.2.1 (JVET-L0335) | 0,07% | 0,08% | 0,08% | 106% | 103% | 32x8x8 bit | 5x4 bit |  |
| CE5.2.2 (JVET-L0094) | -0,01% | -0,01% | -0,01% | 100% | 98% | 32x8x8 bit | 6x5 bit |  |
| 0,04% | 0,05% | 0,05% | 100% | 99% | 32x8x8 bit | 6x4 bit |
| 0,17% | 0,17% | 0,17% | 100% | 98% | 16x8x8 bit | 5x5 bit |
| 0,22% | 0,22% | 0,22% | 100% | 98% | 16x8x8 bit | 5x4 bit |
| CE5.2.3 (JVET-L0461) | 0,05% | 0,05% | 0,05% | 104% | 101% | 32x8x8 bit | n/a |  |
| 0,19% | 0,19% | 0,19% | 104% | 102% | 16x8x8 bit | n/a |
| CE5.2.4 (JVET-L0117) | -0,05% | -0,06% | -0,04% | 101% | 103% | 16x16x8 bit | 6x6 bit | Involves the ‘bit-scan-reverse’ instruction |
| -0,04% | -0,05% | -0,03% | 99% | 98% | 8x16x8 bit | 5x6 bit |
| -0,02% | -0,03% | -0,02% | 102% | 102% | 8x8x8 bit | 5x5 bit |
| RA | CE5.2.1 (JVET-L0335) | 0,08% | 0,08% | 0,08% | 100% | 98% | 32x8x8 bit | 5x4 bit |  |
| CE5.2.2 (JVET-L0094) | 0,00% | 0,00% | 0,00% | 100% | 100% | 32x8x8 bit | 6x5 bit |  |
| 0,06% | 0,06% | 0,06% | 100% | 100% | 32x8x8 bit | 6x4 bit |
| 0,16% | 0,16% | 0,16% | 100% | 100% | 16x8x8 bit | 5x5 bit |
| 0,21% | 0,21% | 0,21% | 100% | 100% | 16x8x8 bit | 5x4 bit |
| CE5.2.3 (JVET-L0461) | 0,05% | 0,05% | 0,05% | 107% | 105% | 32x8x8 bit | n/a |  |
| 0,17% | 0,17% | 0,17% | 107% | 104% | 16x8x8 bit | n/a |
| CE5.2.4 (JVET-L0117) | -0,03% | -0,09% | -0,08% | 111% | 98% | 16x16x8 bit | 6x6 bit | Involves the ‘bit-scan-reverse’ instruction |
| -0,02% | -0,08% | -0,07% | 113% | 100% | 8x16x8 bit | 5x6 bit |
| 0,00% | -0,06% | -0,06% | 115% | 102% | 8x8x8 bit | 5x5 bit |
| LB | CE5.2.1 (JVET-L0335) | 0,07% | 0,07% | 0,07% | 103% | 102% | 32x8x8 bit | 5x4 bit |  |
| CE5.2.2 (JVET-L0094) | -0,05% | -0,05% | -0,05% | 100% | 99% | 32x8x8 bit | 6x5 bit |  |
| 0,03% | 0,02% | 0,02% | 100% | 100% | 32x8x8 bit | 6x4 bit |
| 0,14% | 0,15% | 0,15% | 100% | 100% | 16x8x8 bit | 5x5 bit |
| 0,22% | 0,22% | 0,22% | 100% | 99% | 16x8x8 bit | 5x4 bit |
| CE5.2.3 (JVET-L0461) | 0,03% | 0,03% | 0,03% | 110% | 103% | 32x8x8 bit | n/a |  |
| 0,17% | 0,17% | 0,17% | 111% | 103% | 16x8x8 bit | n/a |
| CE5.2.4 (JVET-L0117) | -0,04% | -0,05% | -0,12% | 104% | 101% | 16x16x8 bit | 6x6 bit | Involves the ‘bit-scan-reverse’ instruction |
| -0,03% | -0,04% | -0,11% | 105% | 103% | 8x16x8 bit | 5x6 bit |
| -0,02% | -0,02% | -0,09% | 105% | 102% | 8x8x8 bit | 5x5 bit |

Further analysis in BoG on throughput – appears there are solutions which reduce the table size without affecting compression performance.

Results of CE5.3.1 are shown relative to CE5.1.4.2 because all tests use the same probability estimator as CE5.1.4.2. Only the coding interval subdivision is different for each test.

**Average test results for subtest 5.3.1 (relative to CE5.1.4.2).**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Averages for Subtest 5.1** | | **Over CE5.1.4.2, VTM configuration** | | | | |  |
| Y | U | V | EncT | DecT | LUT size |
| AI | CE5.3.1.1 | 0,01% | 0,01% | 0,01% | 100% | 101% | 32x8x8 bit |
| CE5.3.1.2 | 0,11% | 0,11% | 0,11% | 100% | 100% | 16x8x8 bit |
| RA | CE5.3.1.1 | 0,01% | 0,01% | 0,01% | 99% | 100% | 32x8x8 bit |
| CE5.2.1.2 | 0,13% | 0,13% | 0,13% | 100% | 99% | 16x8x8 bit |
| LB | CE5.3.1.1 | 0,02% | 0,02% | 0,02% | 99% | 100% | 32x8x8 bit |
| CE5.3.1.2 | 0,15% | 0,14% | 0,14% | 100% | 102% | 16x8x8 bit |

Also include in BoG analysis.

See further notes under BoG report L0XXX.

[JVET-L0057](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4138) CE5: Counter-based probability estimation (Test 5.1.2) [K. Choi, Y. Piao, M. W. Park, K. P. Choi (Samsung)]

[JVET-L0094](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4175) CE5.2.2: CABAC range sub-interval derivation [T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0115](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4196) CE5: Per-context CABAC initialization with double windows (Test 5.1.6) [A. Said, J. Dong, H. Egilmez, Y.-H. Chao, M. Karczewicz, V. Seregin (Qualcomm)]

[JVET-L0116](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4197) CE5: Per-context CABAC initialization with single window (Test 5.1.7) [A. Said, J. Dong, H. Egilmez, Y.-H. Chao, M. Karczewicz, V. Seregin (Qualcomm)]

[JVET-L0117](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4198) CE5: Binary arithmetic coding range update with small table or short multiplications (Test 5.2.4) [A. Said, J. Dong, H. Egilmez, Y.-H. Chao, M. Karczewicz, V. Seregin (Qualcomm)]

[JVET-L0335](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4431) CE5: probability update (5.1.1) and range computation (5.2.1) tests [F. Bossen (Sharp)]

[JVET-L0461](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4565) CE5: Counter-based probability estimation and CABAC coding interval subdivision (CE5.1.3 and CE5.2.3) [P. Haase, J. Stegemann, H. Kirchhoffer, H. Schwarz, D. Marpe, T. Wiegand (HHI)] [late]

[JVET-L0462](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4566) CE5: State-based probability estimation (CE5.1.4, CE5.1.5) and coding interval subdivision (CE5.3.1) [H. Kirchhoffer, C. Bartnik, P. Haase, S. Matlage, J. Stegemann, D. Marpe, H. Schwarz, T. Wiegand (HHI)] [late]

## CE6: Transforms and transform signalling (20)

Contributions in this category were discussed Friday 5 Oct 1115–1330 and 1500-1800 (chaired by JRO).

[JVET-L0026](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4553) CE6: Summary Report on Transforms and Transform Signalling [A. Said, X. Zhao]

This contribution summarizes the activities of Core Experiment (CE) on Transforms and Transform Signalling. The goal of this CE is to study transform design and signalling for the VVC standard. The CE studies were divided into three categories, including:

(1) CE6-1: Primary transforms (21 tests, 11 proposals)

(2) CE6-2: Secondary transform (6 tests, 2 proposals)

(3) CE6-3: and transform combinations and signalling (7 tests, 3 proposals)

In this CE all experiments were done using based on the BMS-2.0.1 SW using VTM configuration. This document summarizes the test results, brief experiment definition, cross-check reports and complexity measurements.

Core experiments (CEs) are organized according to the following three categories, and the following table lists all the experiments in each category, and the corresponding input document to the Macau meeting.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CE6.1 – Primary Transforms** | | | | |
| **CE #** | **Proponent** | **Related Docs.** | **Summary of the tool** | **Cross-checkers** |
| 6.1.1 | LGE | JVET-L0292,  JVET-L0132 | Selection of MTS candidates. Fast DST-7/DCT-8 based on DFT. 32-point MTS based on skipping high frequency coefficients | HHI  B<>com  Qualcomm |
| 6.1.2 | Huawei | JVET-L0358 | Spatially Varying Transform (SVT) for inter blocks | Qualcomm  Sony |
| 6.1.3 | Tencent | JVET-L0285 | Primary transform core with 8-bit precision | Samsung  Huawei  Dolby |
| 6.1.4 | Tencent | JVET-L0285 | Fast DST-7/DCT-8 with dual implementation support | Brightcove  Samsung  Qualcomm  B<>com |
| 6.1.6 | Qualcomm, Orange | JVET-L0386  JVET-L0135 | Efficient Implementations of MTS with Transform Adjustment Stages | Tencent  B<>com |
| 6.1.7 | Panasonic  Technicolor  Sony  Tencent | JVET-L0118  JVET-L0262  JVET-L0486  JVET-L0287 | MTS simplification by reusing DCT-2 partial butterfly | Brightcove  Huawei  Panasonic  Technicolor  Sony  Tencent |
| 6.1.8 | Technicolor | JVET-L0263 | MTS with DCT-II | Sony |

Proposals with goal: Simplification and harmonization

•Transform core reduction

•CE6-1.7a/f/g: Bases sharing between different transform types

Goal is re-using same logic for DCT-2 and the MTS transform bases. Whereas a is keeping the DCT-2 unchanged and changes the other transforms, f/g do it the other way round (designing a new transform COT, “compound orthogonal transform”)

COT is also scalable in the way that all smaller size transforms can be extracted from the length-64 basis.

Transform core precision

- CE6-1.3: 8-bit transform: Uses the same transform bases as HEVC for DCT-2 up to length-32, adds an 8-bit length-64 basis. Likewise, 8-bit versions of the DST-7/DCT-8 are proposed. Results show that there is no significant change in performance (sometimes small gain, sometimes small loss, including HDR). An advantage would be that for 10-bit video, a 16-bit implementation of the transform would be possible.

It is also noted that intentionally VVC should have inherited the 8-bit DCT-2 of HEVC anyway, which was apparently replaced by a 10-bit transform in the initial VTM software.

Decision: Adopt JVET-L0285 (8-bit transform matrices)

Unification of signalling the transform type:

- CE6-1.7b: Currently the switching DST-7/DCT-8 is different for inter and intra. Results indicate that the unification has minor impact on performance. This looks rather like a bug fix. Decision (BF): Adopt JVET-L0118

Fast transform of DST-7/DCT-8

- CE6-1.1c, CE6-1.4, CE6-1.6: fast DST7/DCT8

- CE6-1.1c and CE6-1.4 propose fast algorithms of DST7/DCT8, completely separate from processing of DCT-2. The fast transforms of DST7/DCT8 would also require re-definition of the matrix specifications. CE6-1.6 proposes an initial “adjustment” stage which is a set of filtering operations but could also be specified as matrix multiply, and then performs DCT-2 as is (specification would need to define the inverse operation). To be further investigated in upcoming CE, also considering limitation of arithmetic operations to 16 bit precision.

BoG (X. Zhao): Analysis of complexity, number of cycles to compute inverse transform, necessary bit depth of implementation stages, etc. should be provided (confirmed by proponents). This should also include a comparison versus complexity of fast implementations of DCT-2. See further notes under L0685.

Ideally, the transform should have the following properties:

- Sharing of as much as possible building blocks for different transform types and sizes

- Implementation either as matrix multiply or fast algorithm, independent of specification

- Implementation with 16-bit logic (at least for 10-bit video)

- As low complexity as possible

- Re-usability of legacy building blocks might be desirable

- Specification as matrix multiply, or cascade of matrix multiplies, or other e.g. butterfly

- Extraction of smaller transform sizes from largest size 64 (32 for MTS transforms)

Interesting candidates could be:

- COT with fast implementation similar to 6.1.4

- Aligning of MTS with DCT-2 basis (per 6.1.7a) with fast implementation

- Adjustment preprocessing of 6.1.6

Furthermore, each of the methods should be implementable with 16-bit logic (However, it should be investigated whether this might have impact on low QP cases)

Any additional information on the above aspects w.r.t to these proposals would be welcome.

- CE6-1.1a/b\*: Modified MTS: It is suggested to reduce the number of modes (a suggests using different sets of modes for angular/non-angular, and b suggests only using DST-7). Both cases come with loss in performance, where the loss in b is larger (around 0.3% AI, 0.13% for RA). The main motivation is reduction of encoding time (down to 62% in AI for b). It was mentioned that there is a CE related contribution JVET-0489 which implements the same as encoder only change and has only insignificantly more loss (0.38% AI, 0.2% RA). No action on normative.

- CE6-1.1d: zero-out MTS: Applied for 32xN, Nx32, where half of coefficients is retained, and 32x32, where one quarter is retained, where last coefficient coding is modified. Benefit is not evident (encoder RT 99%, 0.03% loss for RA). It is likely that a similar non-normative approach would not be much different, and doing it normatively would require a specific syntax for the case of 32 blocks. No action.

Proposals with goal: Coding efficiency improvement

Subblock transform

- CE6-1.2: SVT\*: A transform blocks can be split into two halves (left/right or top/bottom), where one half or one quarter of the block is non-zero (8 possible splits in total, the non-zero part is always at a boundary of the block). Depending on position of non-zero area, a specific combination DST-7/DCT-8 is used. There are two versions (a/b), where a has additional conditions on merge, AMVP to invoke the split, whereas in b it can always be used. If the subblock is used, the normal MTS is disabled. Bitrate red. is 0.48% / 0.61% luma for RA, 0.94%/1.02% for LDB for the a/b versions. Encoding time increase is 9%/14%, respectively. It is reported verbally that the gain by using DCT-2 would be significantly lower. The encoding algorithm is already optimized in a way that no full search is done (otherwise the runtime would be significantly higher). The gain becomes lower when inter MTS is enabled (non-CTC). The gain is interesting, but also encoding time increase is not insignificant. In the discussion, it is further emphasized that conceptually a close coupling of subblock transform split and transform selection may be undesirable; the RQT-like concept of transform subblock splitting might be useful for other cases, and an efficient coding that certain splits are beneficial with certain transform types could also be achieved by CABAC context coding. Continue investigation in CE on these aspects.

More flexible MTS

- CE6-1.7 d/e: Adds DST-2 to MTS; d to the current set, and e on top of CE6-1.7a (which replaces DST-7/DCT-8 by DST-4/DCT-4

- CE6-1.8: Includes DCT-2/DST-2, signalling similar to JEM

Generally from this sub-CE, gain is low and would not justify changes. It is noted that some of the loss of CE6-1.7a could be recovered by introducing additional transform.

MTS for larger size

- CE6-1.6c\*: Introduces length-64 MTS transforms. 0.07% in RA CTC (note that the gain for introducing length-64 DCT-2 was much larger). No action at this moment; if a harmonized implementation of all transforms would be available, this might be come for almost no additional implementation cost.

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| **CE6.2 – Secondary Transforms** | | | | |
| **CE #** | **Proponent** | **Related Docs.** | **Summary of the tool** | **Cross-checkers** |
| 6.2.1 | LGE | JVET-L0133 | Reduced secondary transform with one kernel for 35 transform sets. Worst case handled reduced secondary transform with one kernel for 4 transform sets | Tencent  B<>com |
| 6.2.2 | Samsung | JVET-L0058 | Modified NSST sets and signalling | LGE |

All targeting for coding efficiency improvements.

CE6-2.1 a/b/c/d:

- Reduced Size Transform, only keep first 16 coefficients for 8x8 NSST

- Reduced candidates of MTS, only keep {DST-7, DST-7}, MTS index removed

- Worst case handling, reduce multiplications per sample

- Reduced memory size, total 8 4x4 NSST cores, 8 8x8 NSST cores

- NSST selection depends on MTS flag

Reduced Secondary Transform (RST) is investigated with the following aspects.

1. Use one transform kernel per transform set
2. Use only 4 transform set
3. Apply worst case handling method to reduce the number of multiplications
4. Using 2 MTS candidates for Angular mode and 3 candidates for non-angular mode
5. Using 1 MTS candidate for all modes

Note: If restriction b is not invoked, 35 transform sets as of JEM are used.

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| Test # | Description | Tester | Cross-checker |
| 6.2.1-a | a+b+c+e | M. Koo  (LGE) | X. Zhao (Tencent)  B<>com |
| 6.2.1-b | a+b+c+d | M. Koo  (LGE) | Kiho Choi  (Samsung) |
| 6.2.1-c | a+e | M. Koo  (LGE) | X. Zhao (Tencent) |
| 6.2.1-d | a+d | M. Koo  (LGE) | Kiho Choi  (Samsung) |

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|  |  | **All Intra** | | | | | **Random Access** | | | | | **Low Delay B** | | | | |
| **Test #** | **Doc. #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CE6-2.1a | JVET-L0133 | -1.02% | -1.98% | -2.34% | 94% | 96% | -0.58% | -1.37% | -1.73% | 101% | 99% | -0.28% | -0.84% | -1.13% | 100% | 99% |
| CE6-2.1b | JVET-L0133 | -1.16% | -1.86% | -2.21% | 124% | 98% | -0.61% | -1.38% | -1.71% | 109% | 100% | -0.30% | -0.69% | -1.25% | 105% | 100% |
| CE6-2.1c | JVET-L0133 | -1.60% | -2.44% | -2.79% | 92% | 95% | -0.91% | -1.60% | -2.09% | 101% | 100% | -0.40% | -0.79% | -1.22% | 101% | 99% |
| CE6-2.1d | JVET-L0133 | -1.75% | -2.40% | -2.77% | 121% | 96% | -0.93% | -1.65% | -2.11% | 109% | 99% | -0.43% | -0.89% | -1.28% | 104% | 100% |
| CE6-2.2a | JVET-L0058 | -0.60% | -1.70% | -2.40% | 371% | 100% | -0.40% | -1.60% | -2.20% | 177% | 101% | -0.20% | -0.70% | -1.30% | 137% | 100% |
| CE6-2.2b | JVET-L0058 | -1.80% | -2.60% | -3.20% | 383% | 103% | -1.00% | -2.20% | -2.60% | 185% | 101% | -0.40% | -1.30% | -1.70% | 143% | 100% |

The run time reduction of 2.1a and 2.1c comes due to restriction of MTS candidate checking (and change of syntax for MTS). NSST by itself would increase the run time by 30-35% in AI.

When the NSST is applied on part of the transform coefficients (maximum 8x8 region), the remaining coefficients are zeroed.

The most interesting solution is 2.1a/b which uses only 4 transform sets.

The highest possible luma gain of NSST (when nothing is modified with MTS) with 35 transform sets would be around 2.2% for AI, 1.2% for RA. The case with 4 transform sets loses around 0.3% compared to that from the table above.

The transform requires implementation as matrix multiply, in worst case 8 mult/sample. This is an additional stage in the decoder. However, looking at the possible gain, this could be asserted as still an attractive performance/complexity tradeoff. Also, the method of reducing worst case number of multiplications appears to be straightforward (restrictions for small block sizes). However, some concern is raised about the fact that this is a new building block with not insignificant complexity impact. More detailed study of the new proposal (W. Wan to report back).

Proponents are requested to provide results with only “a+b+c” under CTC as per table above, to assess the runtime versus performance benefit of NSST standalone.

Results were made available in v4. The luma gain is 1.13% average for AI, 0.59% for RA. Runtime increase is to 139% for AI, 113% for RA. This is around half the gain of the NSST of BMS.

The transform is non-separable and needs to be implemented by matrix multiply. The largest matrix would be 64x16 (for any block >=8x8), worst case is 8x8 block.

Gain is not justifying the additional complexity. Further study (CE) what the gain would be if it is only applied to a 4x4 group of transform coefficients (which would be a 16x16 matrix operation). Study cases where the subset of transform coefficients is small (1/4 or less) compared to the transform block size. Study only the effect of secondary transform, not combination with modifying other building blocks.

Solution 6.2.2x is not attractive in terms of runtime.

CE6-2.3 a/b:

•NSST based on explicit signalling, flag and index

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| **CE6.3 – Combinations and Signalling** | | | | |
| **CE #** | **Proponent** | **Related Docs.** | **Summary of the tool** | **Cross-checkers** |
| 6.3.1 | HHI | JVET-L0261 | **Set of transforms:** A set of predefined transform candidates, and each candidate specifies a primary horizontal transform, a primary vertical transform, and a non-separable secondary transform. The transform candidates depend on the block size and the prediction mode. | Brightcove  Tencent  LGE |
| 6.3.2 | Tencent | JVET-L0288 | Coupled primary and secondary transform | LGE  HHI  B<>com |
| 6.3.3 | Qualcomm | JVET-L0387 | Secondary Transforms Coupled with Simplified Primary Transformation | HHI  Tencent |

The proposals investigate combining primary and secondary transforms (incl. combined signalling)

CE6-3.1 b/c

•NSST selection coupled with MTS index

•MTS selection specified by a new block-size dependent LUT

•4x4 NSST based on HyGT (as BMS), 8x8 NSST based on HSMT (different from BMS)

•CE6-3.2 a/b/c

•NSST selection coupled with MTS index

•MTS index signalling modified from 2-bit fix-length to TUC

•Matrix multiplication based NSST, only 4x4 proposed (different from BMS)

•CE6-3.3 a/b

•MTS only use {DST-7, DST-7}

•NSST selection coupled with MTS index

•8x8 NSST based on HSMT (same as 6-3.1)

From the results shown in CE6-3, the secondary transform of CE6-2.1 appears to give a better tradeoff in terms of performance and complexity reduction that was achieved relative to the BMS NSST.

[JVET-L0058](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4139) CE6: NSST with modified NSST sets and signalling (Test 6.2.3) [K. Choi, M. Park, M. W. Park, K. P. Choi (Samsung)]

[JVET-L0118](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4199) CE6: Type4 MTS and index alignment (Test 6.1.7-b, 6.1.7-c) [K. Abe, T. Toma (Panasonic)]

[JVET-L0132](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4213) CE6-1.1 (c,d): Fast DST-7/DCT-8 based on DFT and 32 point MTS based on skipping high frequency coefficients [M. Koo, M. Salehifar, J. Lim, S. Kim (LGE)]

[JVET-L0133](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4214) CE6-2.1: Reduced Secondary Transform (RST) [M. Koo, M. Salehifar, J. Lim, S. Kim (LGE)]

[JVET-L0135](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4216) CE6: Further simplification of MTS with adjustment stages (Test CE6.1.6b) [P. Philippe (Orange), V. Lorcy (bcom)]

[JVET-L0261](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4356) CE6 – Set of Transforms (Tests 6.3.1) [M. Siekmann, C. Bartnik, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

[JVET-L0262](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4357) CE6-1.7a: MTS simplification by reusing DCT-2 partial butterfly - Change MTS transform to DST-4/DCT-4 [K. Abe, T. Toma (Panasonic), M. Ikeda, T. Tsukuba (Sony), K. Naser, F. Le Leannec, E. François (Technicolor)]

[JVET-L0263](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4358) CE6-1.8: MTS with DCT-II [K. Naser, F. Le Leannec, E. François (Technicolor)]

[JVET-L0285](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4380) CE6: On 8-bit primary transform core (Test 6.1.3) [X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-L0286](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4381) CE6: Fast DST-7/DCT-8 with dual implementation support (Test 6.1.4) [X. Zhao, X. Li, Y. Luo, S. Liu (Tencent)]

[JVET-L0287](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4382) CE6: Compound Orthonormal Transform (Test 6.1.7 f/g) [X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-L0288](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4383) CE6: Coupled primary and secondary transform (Test 6.3.2) [X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-L0649](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4763) Cross-check of JVET-L0288 (CE6: Coupled Primary and Secondary Transform) [M. Salehifar (LGE)] [late]

[JVET-L0292](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4387) CE6-1.1 (a,b): Selection of MTS Candidates [M. Salehifar, M. Koo, J. Lim, S. Kim (LGE)]

[JVET-L0358](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4455) CE6: Sub-block transform for inter blocks (CE6.1.2) [Y. Zhao, H. Yang, J. Chen (Huawei)] [late]

[JVET-L0386](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4483) CE6.1.6: Efficient Implementations of MTS with Transform Adjustment Filters (TAF) [A. Said, H. Egilmez, Y.-H. Chao, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-L0512](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4618) Crosscheck of JVET-L0386 (Approximation of 32x32 DCT-4 in DCT-2 implementation) [P. Philippe (Orange), V. Lorcy (bcom)] [late]

[JVET-L0387](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4484) CE6.3.3: Secondary Transforms Coupled with a Simplified Primary Transformation [H. Egilmez, A. Said, Y.-H. Chao, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-L0486](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4590) CE6: Add DST-2/DCT-2 and switch MTS candidate depending on intra direction (CE6-1.7d and CE6-1.7e) [T. Tsukuba, M. Ikeda, T. Suzuki (Sony), K. Naser, E. Francois (Technocolor)] [late]

## CE7: Quantization and coefficient coding (7)

Contributions in this category were discussed Friday 5 Oct 1815–1950 (chaired by JRO).

[JVET-L0027](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4563) CE7: Summary report on quantization and coefficient coding [H. Schwarz, M. Coban, C. Auyeng]

The CE report summarizes the test results and crosschecks reports for CE7 on quantization and coefficient coding. The CE includes the following sub-CEs:

* CE 7.1: Transform coefficient coding (4 tests)
* CE 7.2: Block adaptive quantization / residual coding (7 tests)
* CE 7.3: Transform coefficient scanning (3 tests)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **sub CE** | **test** | **tester** | **doc.** | **short description** |
| **7.1** | 7.1.1 | C. Auyeung | L0397 | complexity reduction of context model selection |
| 7.1.2 | M. Coban | L0384 | entropy coding for dependent quantization (sig-based) |
| 7.1.3 | H. Schwarz | L0274 | reduction of number of context-coded bins (two versions) |
| 7.1.4 | *withdrawn* | | |
| **7.2** | 7.2.1 | Y. Zhao | L0360 | adaptive residual scaling (two versions) |
| 7.2.2 | Y. Zhao | L0360 | adaptive residual scaling for large blocks only |
| 7.2.3 | Y. Zhao | L0360 | non-normative delta QP selection (based on measures for ARS, two versions) |
| 7.2.4 | *withdrawn* | | |
| 7.2.5 | *withdrawn* | | |
| 7.2.6 | C. Helmrich | L0210 | VTM-2.1 non-normative QP adaptation (two versions) |
| **7.3** | 7.3.1 | Y. Kidani | L0379 | block size dependent coefficient scanning |
| 7.3.2 | Y. Kidani | L0379 | block size dependent coefficient scanning with NSST |
| 7.3.3 | Y. Kidani | L0379 | block size dependent coefficient scanning for low QPs |

It was noted that 7.1.3b came late in the CE and the change in binarization was not reflected in CE description.

The goal of CE7.1 is simplification of various aspects. In the last meeting, concern was expressed that the possible maximum number of context coded bins with dependent quantization is significantly larger than it was in HEVC.

7.1.1 simplifies the position dependency of context selection (except for the subblock which includes the DC coefficient). This is however not helping in worst case complexity, as every TB could be 4x4.

7.1.2. changes the state machine (sig based rather than parity based), and performs coefficient coding similar to JEM. Number of context-coded bins per subblock is limited by a counter mechanism.

7.1.3a is VTM, number of context-coded bins per subblock is limited by a counter mechanism.

7.1.3b is additionally changing the binarization.

7.1.1 and 7.1.3a have marginal impact on rate, 7.1.2 has losses (approx. 0.2% in AI and RA, no in LDB)

7.1.3b has some compression gain 0.07% RA, 0.18% AI

7.1.2 and 7.1.3 have increase in encoder runtime, which is asserted that it can be solved by removing some if statements in rate estimation.

Decision: Adopt JVET-L0274, version 7.1.3b.

CE7.2 is investigating approaches of subjectively optimized quantizer adaptation. 7.2.1 and 7.2.2 are normative solutions, 7.2.3/7.2.6 are non-normative.

Generally, it can be concluded that non-normative exist which are (when judged by MS-SSIM, provided that would match the visual quality) similar or better than the normative ones.

This is however not surprising, as typically subjective optimization is expected to give visible quality improvement at same bit rate, and various methods exist for that.

7.2.1 and 7.2.3 are using basically the same approach for local quantizer adaptation, and comparing the BD rate results either in MS-SSIM or PSNR shows about 2% rate saving by not transmitting quantization parameters.

On the other hand, subjective adaptation of quantizers is widely used, but there are many different methods that are applied practically. Therefore, encoder manufacturers might likely prefer using their own method (and spend 2% additional rate), rather than using something that is hard-coded. Furthermore, it is asserted that rate saving achievable by sophisticated quantizer adaptation (for same visual quality) is typically much higher than 2%.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **CE 7.2** | | **MS-SSIM** | | | | | **PSNR** | | | | |
| Y | U | V | encT | decT | Y | U | V | encT | decT |
| **AI** | 7.2.1a | -5.24% | 0.23% | 0.12% | 103% | 103% | 2.54% | 0.55% | 0.47% | 103% | 103% |
| 7.2.1b | -3.74% | 0.17% | 0.14% | 102% | 104% | 2.02% | 0.43% | 0.41% | 102% | 104% |
| 7.2.2 | -4.14% | -0.04% | -0.12% | 102% | 103% | 2.65% | 0.11% | 0.09% | 102% | 103% |
| 7.2.3a | -2.90% | -1.22% | -1.25% | 101% | 100% | 0.98% | -1.26% | -1.25% | 101% | 100% |
| 7.2.3b | -4.66% | -1.97% | -2.09% | 100% | 103% | 3.01% | -1.94% | -1.98% | 100% | 103% |
| 7.2.6a | -5.54% | -4.43% | -6.69% | 114% | 104% | 3.37% | -4.70% | -5.56% | 114% | 104% |
| 7.2.6b | -4.13% | -15.74% | -17.81% | 114% | 104% | 4.98% | -15.86% | -16.68% | 114% | 104% |
| **RA** | 7.2.1a | -5.81% | 1.37% | 0.97% | 103% | 102% | 2.72% | 2.38% | 2.12% | 103% | 102% |
| 7.2.1b | -3.56% | -0.30% | -0.34% | 100% | 102% | 2.17% | -0.07% | -0.10% | 100% | 102% |
| 7.2.2 | -4.77% | 1.23% | 0.97% | 103% | 102% | 2.85% | 2.23% | 1.96% | 103% | 102% |
| 7.2.3a | -2.91% | -0.21% | 0.14% | 104% | 100% | 1.01% | 0.51% | 0.97% | 104% | 100% |
| 7.2.3b | -4.70% | 0.54% | 0.81% | 105% | 101% | 3.20% | 1.99% | 2.49% | 105% | 101% |
| 7.2.6a | -8.23% | 12.76% | 8.58% | 101% | 99% | 3.94% | 12.62% | 10.71% | 101% | 99% |
| 7.2.6b | -6.96% | -2.10% | -5.85% | 102% | 98% | 5.34% | -2.22% | -3.57% | 102% | 98% |
| **LB** | 7.2.1a | -5.99% | 4.87% | 3.90% | 99% | 102% | 3.48% | 6.13% | 5.22% | 99% | 102% |
| 7.2.1b | -3.13% | -1.78% | -2.42% | 95% | 102% | 2.72% | -1.94% | -2.47% | 95% | 102% |
| 7.2.2 | -4.68% | 4.43% | 3.37% | 98% | 100% | 3.71% | 5.47% | 4.49% | 98% | 100% |
| 7.2.3a | -2.41% | 1.34% | 0.99% | 101% | 99% | 1.59% | 2.27% | 1.95% | 101% | 99% |
| 7.2.3b | -4.25% | 4.17% | 3.90% | 101% | 101% | 4.29% | 6.12% | 5.69% | 101% | 101% |
| 7.2.6a | -4.50% | 14.48% | 10.19% | 112% | 104% | 7.29% | 13.25% | 10.59% | 112% | 104% |
| 7.2.6b | -3.70% | -5.21% | -9.00% | 113% | 100% | 8.28% | -6.33% | -8.54% | 113% | 100% |

7.3: Mode dependent coefficient scanning

Similar to HM/JEM: Scan order depends on intra prediction mode (hor, ver, diag)

Difference to HM/JEM: Multiple scans are only supported for selected block sizes (diagonal scan is used for other block sizes)

* Test 7.3.1: As proposed
* Test 7.3.2: NSST is additionally enabled in tested version and reference
* Test 7.3.3: Same as7.3.1, but for QP range 12, 17, 22, 27

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **CE 7.3** | | Y | U | V | encT | decT |
| **AI** | 7.3.1 | -0.08% | -0.09% | -0.07% | 101% | 101% |
| 7.3.2 | 0.01% | -0.03% | -0.03% | 101% | 100% |
| 7.3.3 | -0.04% | -0.07% | -0.08% | 101% | 101% |
| **RA** | 7.3.1 | -0.03% | -0.07% | 0.00% | 101% | 100% |
| 7.3.2 | 0.01% | -0.01% | -0.02% | 100% | 100% |
| 7.3.3 | -0.01% | -0.06% | -0.03% | 101% | 101% |
| **LB** | 7.3.1 | -0.06% | 0.08% | -0.10% | 100% | 101% |
| 7.3.2 | -0.02% | 0.18% | 0.08% | 100% | 100% |
| 7.3.3 | -0.03% | 0.13% | 0.06% | 100% | 100% |

The gain is low, and mode dependent scanning would introduce additional building blocks, more specification text and potentially has parsing dependency problems (as in HEVC). No action, VVC stays without mode dependent scanning.

[JVET-L0210](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4301) CE7: Adaptive quantization via perceptually optimized QP adaptation (Test 7.2.6) [C. Helmrich (HHI)]

[JVET-L0274](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4370) CE7: Transform coefficient coding with reduced number of regular-coded bins (tests 7.1.3a, 7.1.3b) [H. Schwarz, T. Nguyen, D. Marpe, T. Wiegand (Fraunhofer HHI), M. Karczewicz, M. Coban, J. Dong (Qualcomm)]

[JVET-L0360](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4457) CE7: Adaptive residual scaling (CE7.2.1, CE7.2.2, CE7.2.3) [Y. Zhao, H. Yang, J. Chen (Huawei)] [late]

[JVET-L0379](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4476) CE7: Block size dependent coefficient scanning (CE7.3) [Y. Kidani, K. Kawamura, S. Naito (KDDI)]

[JVET-L0384](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4481) CE7: Entropy Coding for Dependent Quantization (test 7.1.2) [J. Dong, M. Coban, M. Karczewicz (Qualcomm)]

[JVET-L0397](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4494) CE7: Complexity reduction of context model selection of transform coefficient levels [C. Auyeung, J. Chen (Huawei)]

## CE8: Current picture referencing (6)

Contributions in this category were discussed Thursday 4 Oct 2000–2115 (chaired by JRO).

[JVET-L0028](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4433) CE8: Summary Report on Current Picture Referencing [X. Xu, K. Müller, L. Wang]

This contribution provides a summary report of Core Experiment 8 on current picture referencing. Four tests have been agreed to carry out in CE8 in between JVET-K and JVET-L meetings, to study and evaluate technologies related to current picture referencing. In this report, coding performance and complexity of these tests are reported and analyzed. In particular, test results against 1) VTM-2 anchor 2) VTM-2 + CPR anchor are provided to show the coding efficiency and complexity trade-off of each tool. Crosschecking results for the performed tests are integrated in this contribution.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Test** | **Tester** | **Doc.** | **Tool description** | **Cross checker** |
| 8.1 | [G. Venugopal](mailto:gayathri.venugopal@hhi.fraunhofer.de)  (HHI) | JVET-L0077 | Intra region-based template matching | V. Drugeon  ( Panasonic) |
| 8.2 | X. Xu  (Tencent) | JVET-L0290 | Current picture referencing with separate trees | X. Zheng  (DJI) |
| 8.3 | X. Xu  (Tencent) | JVET-L0293 | Current picture referencing with constraints   1. Allow CPR coded block to be compensated only from the current CTU 2. Allow CPR coded block to be compensated only from the current CTU and the CTU to its left | [G. Venugopal](mailto:gayathri.venugopal@hhi.fraunhofer.de)  (HHI)  Y.-W. Chen  (Kwai) |
|  | X. Xu  (Tencent) | JVET-L0295 | Current picture referencing with constraints   1. Exclude the current CTU and the CTU to its left from CPR compensation area 2. Exclude the current CTU and the CTU to its left from CPR compensation area. In addition, disable all loop-filters 3. Exclude the current CTU and the two CTUs to its left from CPR compensation area 4. Exclude the current CTU and the two CTUs to its left from CPR compensation area. In addition, disable all loop-filters | K. Zhang  (ByteDance)  W. Zhu  (Sharp) |

8.1: It is reported that template matching was further simplified relative to the method presented at last meeting. The results are with a search area that goes into the above row of CTUs (approx. 80 lines buffer would be needed. Search area restricted to current CTU and CTU left is 0.77% in AI under CTC.

8.2: If the corresponding luma block is CPR mode, the vector inherited from luma (& scaled). Otherwise, CPR is not used in chroma. The approach uses “special” P slices at IRAP positions which can only use CPR or I mode blocks.

8.3: The tests in JVET-L0295 were made to limit exclusive usage of off-chip memory. The solution of disabling the loop filter is undesirable, as it ends up with significant loss in particular for natural images.

Results:

Note that in the subsequent tables “BMS CPR full frame version” is with dual tree support. “CPR dual tree support off” is switching off the dual tree of 8.2 (in P slices), as well as the dual tree of I slices, therefore it has loss compared to VTM.

CE8 test results against VTM anchor

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  | **AI Over VTM-2.0.1** |  |  |  |  | **RA Over VTM-2.0.1** |  |  |  |  | **LDB Over VTM-2.0.1** |  |  |
|  | **Test#** | Test description | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CTC overall | BMS | CPR full frame version | -0.39% | -0.48% | -0.41% | 141% | 97% | -0.14% | -0.23% | -0.26% | 109% | 103% | 0.00% | 0.08% | -0.04% | 116% | 103% |
| CE8.1 | Intra-Template-Matching | -1.01% | -0.85% | -0.91% | 131% | 103% | -0.35% | -0.31% | -0.31% | 107% | 101% | -0.15% | -0.25% | -0.40% | 104% | 100% |
| CE8.2 | CPR dual-tree support off | 1.17% | -5.57% | -5.33% | 210% | 104% | 0.02% | 0.79% | 1.01% | 112% | 105% | 0.08% | -1.21% | -0.50% | 118% | 106% |
| CE8.3.1a | Only current CTU | -0.16% | -0.25% | -0.16% | 139% | 104% | -0.07% | -0.22% | -0.14% | 109% | 105% | 0.02% | 0.13% | -0.11% | 117% | 106% |
| CE8.3.1b | Only current CTU, no chroma interpolation | -0.18% | -0.24% | -0.19% | 137% | 104% | -0.07% | -0.21% | -0.12% | 109% | 105% | 0.03% | 0.23% | -0.03% | 117% | 106% |
| CE8.3.2a | Only current and left 1 CTU | -0.29% | -0.38% | -0.30% | 145% | 104% | -0.10% | -0.26% | -0.17% | 109% | 105% | 0.02% | 0.15% | -0.04% | 117% | 105% |
| CE8.3.2b | Only current and left 1 CTU, no chroma ip | -0.31% | -0.39% | -0.31% | 143% | 104% | -0.09% | -0.19% | -0.18% | 110% | 105% | 0.03% | 0.16% | -0.18% | 117% | 106% |
| CE8.3.3 | Exclude cur and left 1 CTU | 0.18% | 0.10% | 0.19% | 112% | 98% | 0.02% | -0.05% | 0.08% | 99% | 99% | 0.04% | 0.10% | 0.00% | 105% | 99% |
| CE8.3.4 | Exclude cur and left 1 CTU, no in-loop filters | 4.03% | 8.29% | 9.98% | 117% | 81% | 10.60% | 7.07% | 6.61% | 105% | 77% | 7.94% | 8.82% | 11.12% | 112% | 85% |
| CE8.3.5 | Exclude cur and left 2 CTUs | 0.18% | 0.10% | 0.19% | 112% | 98% | 0.02% | -0.05% | 0.08% | 99% | 99% | 0.04% | 0.10% | 0.00% | 106% | 99% |
| CE8.3.6 | Exclude cur and left 2 CTUs, no in-loop filters | 4.03% | 8.28% | 9.98% | 117% | 82% | 10.60% | 7.07% | 6.60% | 105% | 78% | 7.94% | 8.82% | 11.12% | 112% | 84% |
| Class F | BMS | CPR full frame version | -17.62% | -17.72% | -17.79% | 174% | 91% | -14.49% | -14.62% | -14.67% | 121% | 98% | -8.49% | -8.54% | -8.74% | 117% | 101% |
| CE8.1 | Intra-Template-Matching | -8.19% | -8.05% | -8.16% | 125% | 110% | -6.34% | -6.26% | -6.17% | 109% | 101% |  |  |  |  |  |
| CE8.2 | CPR dual-tree support off | -16.62% | -21.54% | -20.48% | 230% | 98% | -14.44% | -15.56% | -15.13% | 129% | 101% | -8.52% | -10.03% | -9.80% | 119% | 104% |
| CE8.3.1a | Only current CTU | -11.61% | -11.82% | -11.87% | 155% | 102% | -9.63% | -9.93% | -9.88% | 115% | 102% | -5.21% | -5.19% | -6.23% | 118% | 105% |
| CE8.3.1b | Only current CTU, no chroma interpolation | -11.87% | -11.98% | -12.01% | 153% | 101% | -9.73% | -9.88% | -9.91% | 115% | 101% | -5.20% | -4.83% | -5.40% | 116% | 103% |
| CE8.3.2a | Only current and left 1 CTU | -15.49% | -15.61% | -15.61% | 168% | 98% | -12.67% | -12.73% | -12.79% | 118% | 101% | -7.16% | -7.48% | -7.85% | 117% | 103% |
| CE8.3.2b | Only current and left 1 CTU, no chroma ip | -15.60% | -15.58% | -15.62% | 164% | 99% | -12.69% | -12.63% | -12.63% | 117% | 101% | -7.06% | -6.91% | -6.75% | 117% | 103% |
| CE8.3.3 | Exclude cur and left 1 CTU | -8.18% | -8.35% | -8.33% | 143% | 94% | -7.28% | -7.39% | -7.31% | 108% | 96% | -3.88% | -3.95% | -4.53% | 106% | 96% |
| CE8.3.4 | Exclude cur and left 1 CTU, no in-loop filters | -4.98% | -4.04% | -4.25% | 148% | 79% | -2.75% | -3.71% | -3.81% | 111% | 84% | 3.56% | 4.92% | 6.38% | 112% | 87% |
| CE8.3.5 | Exclude cur and left 2 CTUs | -7.43% | -7.62% | -7.62% | 144% | 93% | -6.62% | -6.70% | -6.68% | 108% | 96% | -3.44% | -3.49% | -3.70% | 106% | 95% |
| CE8.3.6 | Exclude cur and left 2 CTUs, no in-loop filters | -4.21% | -3.29% | -3.50% | 150% | 80% | -2.07% | -3.01% | -3.22% | 111% | 85% | 4.17% | 5.78% | 7.19% | 112% | 86% |
| SCC 1080p | BMS | CPR full frame version | -52.82% | -52.12% | -52.43% | 154% | 88% | -35.62% | -35.65% | -36.06% | 107% | 92% | -25.29% | -26.53% | -26.50% | 116% | 98% |
| CE8.1 | Intra-Template-Matching | -23.08% | -22.05% | -22.28% | 112% | 117% | -11.97% | -11.49% | -11.70% | 107% | 102% |  |  |  |  |  |
| CE8.2 | CPR dual-tree support off | -53.19% | -52.80% | -52.92% | 188% | 85% | -35.61% | -35.15% | -35.51% | 111% | 95% | -25.25% | -26.60% | -26.66% | 117% | 102% |
| CE8.3.1a | Only current CTU | -36.51% | -35.89% | -36.20% | 148% | 99% | -22.76% | -22.82% | -23.10% | 110% | 97% | -13.98% | -14.73% | -14.75% | 121% | 106% |
| CE8.3.1b | Only current CTU, no chroma interpolation | -36.60% | -35.84% | -36.13% | 145% | 98% | -22.36% | -21.99% | -22.47% | 109% | 97% | -13.42% | -13.86% | -14.04% | 120% | 105% |
| CE8.3.2a | Only current and left 1 CTU | -46.10% | -45.32% | -45.67% | 151% | 92% | -29.42% | -29.36% | -29.71% | 109% | 97% | -19.40% | -20.32% | -20.31% | 119% | 104% |
| CE8.3.2b | Only current and left 1 CTU, no chroma ip | -45.73% | -44.81% | -45.09% | 149% | 94% | -28.69% | -28.21% | -28.75% | 108% | 96% | -18.36% | -18.84% | -19.09% | 119% | 103% |
| CE8.3.3 | Exclude cur and left 1 CTU | -35.00% | -34.92% | -35.06% | 139% | 90% | -21.52% | -21.87% | -22.00% | 101% | 92% | -14.35% | -14.98% | -14.87% | 108% | 99% |
| CE8.3.4 | Exclude cur and left 1 CTU, no in-loop filters | -32.93% | -34.64% | -34.65% | 147% | 79% | -16.91% | -21.43% | -21.38% | 106% | 79% | -5.23% | -12.25% | -11.84% | 117% | 86% |
| CE8.3.5 | Exclude cur and left 2 CTUs | -32.62% | -32.49% | -32.63% | 143% | 92% | -19.71% | -19.95% | -20.11% | 101% | 93% | -12.91% | -13.40% | -13.40% | 109% | 101% |
| CE8.3.6 | Exclude cur and left 2 CTUs, no in-loop filters | -30.44% | -32.21% | -32.23% | 151% | 80% | -14.86% | -19.51% | -19.40% | 107% | 80% | -3.32% | -10.26% | -9.88% | 118% | 86% |

CE8 test results against VTM+CPR anchor

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  | **AI Over VTM-2.0.1** |  |  |  |  | **RA Over VTM-2.0.1** |  |  |  |  | **LDB Over VTM-2.0.1** |  |  |
|  | **Test#** | Test description | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CTC overall | BMS | CPR full frame version | 0.00% | 0.00% | 0.00% | 100% | 100% | 0.00% | 0.00% | 0.00% | 100% | 100% | 0.00% | 0.00% | 0.00% | 100% | 100% |
| CE8.1 | Intra-Template-Matching | -0.69% | -0.56% | -0.57% | 120% | 102% | -0.19% | -0.33% | -0.14% | 105% | 99% | -0.03% | -0.20% | 0.11% | 101% | 96% |
| CE8.2 | CPR dual-tree support off | 1.56% | -5.11% | -4.92% | 141% | 99% | 0.16% | 1.03% | 1.29% | 103% | 102% | 0.08% | -1.27% | -0.46% | 101% | 103% |
| CE8.3.1a | Only current CTU | 0.23% | 0.24% | 0.25% | 93% | 100% | 0.08% | 0.02% | 0.12% | 99% | 102% | 0.02% | 0.06% | -0.07% | 101% | 104% |
| CE8.3.1b | Only current CTU, no chroma interpolation | 0.21% | 0.24% | 0.22% | 93% | 100% | 0.08% | 0.02% | 0.14% | 99% | 102% | 0.04% | 0.16% | 0.01% | 100% | 103% |
| CE8.3.2a | Only current and left 1 CTU | 0.10% | 0.10% | 0.11% | 97% | 100% | 0.05% | -0.03% | 0.10% | 100% | 102% | 0.02% | 0.07% | 0.00% | 101% | 103% |
| CE8.3.2b | Only current and left 1 CTU, no chroma ip | 0.08% | 0.10% | 0.10% | 96% | 100% | 0.05% | 0.04% | 0.08% | 100% | 102% | 0.04% | 0.08% | -0.14% | 101% | 103% |
| CE8.3.3 | Exclude cur and left 1 CTU | 0.57% | 0.59% | 0.61% | 75% | 94% | 0.16% | 0.19% | 0.34% | 90% | 96% | 0.05% | 0.03% | 0.03% | 91% | 96% |
| CE8.3.4 | Exclude cur and left 1 CTU, no in-loop filters | 4.44% | 8.82% | 10.46% | 79% | 78% | 10.77% | 7.34% | 6.90% | 96% | 75% | 7.95% | 8.77% | 11.22% | 96% | 83% |
| CE8.3.5 | Exclude cur and left 2 CTUs | 0.57% | 0.59% | 0.60% | 75% | 94% | 0.16% | 0.18% | 0.34% | 90% | 96% | 0.05% | 0.03% | 0.03% | 91% | 97% |
| CE8.3.6 | Exclude cur and left 2 CTUs, no in-loop filters | 4.44% | 8.82% | 10.46% | 79% | 78% | 10.77% | 7.34% | 6.89% | 96% | 76% | 7.95% | 8.77% | 11.22% | 97% | 82% |
| Class F | BMS | CPR full frame version | 0.00% | 0.00% | 0.00% | 100% | 100% | 0.00% | 0.00% | 0.00% | 100% | 100% | 0.00% | 0.00% | 0.00% | 100% | 100% |
| CE8.1 | Intra-Template-Matching | -1.03% | -0.66% | -0.44% | 114% | 105% | -0.48% | -0.27% | -0.32% | 107% | 101% |  |  |  |  |  |
| CE8.2 | CPR dual-tree support off | 1.11% | -4.56% | -2.64% | 125% | 98% | 0.00% | -1.37% | -0.52% | 106% | 103% | -0.03% | -1.83% | -1.20% | 102% | 102% |
| CE8.3.1a | Only current CTU | 9.71% | 9.45% | 9.49% | 84% | 102% | 7.83% | 7.54% | 7.69% | 95% | 104% | 4.47% | 4.48% | 3.61% | 101% | 103% |
| CE8.3.1b | Only current CTU, no chroma interpolation | 9.29% | 9.19% | 9.29% | 83% | 101% | 7.66% | 7.56% | 7.64% | 95% | 103% | 4.47% | 4.92% | 4.51% | 99% | 101% |
| CE8.3.2a | Only current and left 1 CTU | 3.56% | 3.51% | 3.60% | 91% | 98% | 3.05% | 3.09% | 3.11% | 97% | 103% | 1.85% | 1.54% | 1.37% | 100% | 102% |
| CE8.3.2b | Only current and left 1 CTU, no chroma ip | 3.37% | 3.53% | 3.58% | 89% | 99% | 3.00% | 3.21% | 3.30% | 97% | 104% | 1.99% | 2.21% | 2.59% | 100% | 101% |
| CE8.3.3 | Exclude cur and left 1 CTU | 14.58% | 14.30% | 14.46% | 78% | 94% | 11.27% | 11.19% | 11.39% | 89% | 98% | 6.20% | 6.14% | 5.69% | 91% | 95% |
| CE8.3.4 | Exclude cur and left 1 CTU, no in-loop filters | 18.34% | 19.21% | 19.10% | 80% | 79% | 16.36% | 15.09% | 15.12% | 92% | 86% | 14.36% | 15.22% | 16.94% | 96% | 86% |
| CE8.3.5 | Exclude cur and left 2 CTUs | 15.79% | 15.49% | 15.62% | 78% | 93% | 12.33% | 12.26% | 12.39% | 90% | 98% | 6.82% | 6.81% | 6.74% | 90% | 94% |
| CE8.3.6 | Exclude cur and left 2 CTUs, no in-loop filters | 19.58% | 20.43% | 20.32% | 81% | 79% | 17.44% | 16.17% | 16.06% | 92% | 86% | 15.18% | 16.35% | 17.90% | 95% | 85% |
| SCC 1080p | BMS | CPR full frame version | 0.00% | 0.00% | 0.00% | 100% | 100% | 0.00% | 0.00% | 0.00% | 100% | 100% | 0.00% | 0.00% | 0.00% | 100% | 100% |
| CE8.1 | Intra-Template-Matching | -0.85% | -0.02% | 0.04% | 111% | 112% | -0.32% | -0.05% | -0.04% | 105% | 104% |  |  |  |  |  |
| CE8.2 | CPR dual-tree support off | -1.29% | -2.20% | -2.43% | 122% | 97% | -0.10% | 0.41% | 0.42% | 104% | 103% | 0.03% | -0.28% | -0.37% | 102% | 105% |
| CE8.3.1a | Only current CTU | 38.55% | 37.92% | 38.21% | 96% | 103% | 22.15% | 22.01% | 22.26% | 103% | 105% | 16.27% | 17.02% | 16.94% | 105% | 108% |
| CE8.3.1b | Only current CTU, no chroma interpolation | 38.42% | 38.07% | 38.43% | 94% | 101% | 22.73% | 23.20% | 23.18% | 102% | 105% | 16.94% | 18.10% | 17.82% | 104% | 107% |
| CE8.3.2a | Only current and left 1 CTU | 15.62% | 15.65% | 15.69% | 98% | 98% | 10.56% | 10.67% | 10.79% | 102% | 105% | 8.47% | 8.91% | 8.89% | 103% | 106% |
| CE8.3.2b | Only current and left 1 CTU, no chroma ip | 16.62% | 16.88% | 17.10% | 97% | 100% | 11.69% | 12.37% | 12.23% | 101% | 104% | 9.79% | 10.83% | 10.49% | 103% | 106% |
| CE8.3.3 | Exclude cur and left 1 CTU | 41.24% | 39.23% | 39.85% | 90% | 95% | 23.91% | 23.27% | 23.75% | 94% | 100% | 15.77% | 16.62% | 16.75% | 93% | 101% |
| CE8.3.4 | Exclude cur and left 1 CTU, no in-loop filters | 45.68% | 39.68% | 40.50% | 96% | 80% | 30.42% | 23.64% | 24.36% | 99% | 86% | 26.77% | 19.83% | 20.31% | 101% | 88% |
| CE8.3.5 | Exclude cur and left 2 CTUs | 47.41% | 45.37% | 46.05% | 93% | 94% | 27.25% | 26.72% | 27.19% | 95% | 100% | 17.96% | 19.02% | 18.98% | 94% | 103% |
| CE8.3.6 | Exclude cur and left 2 CTUs, no in-loop filters | 52.16% | 45.81% | 46.68% | 98% | 80% | 34.13% | 27.11% | 27.92% | 100% | 87% | 29.60% | 22.79% | 23.26% | 102% | 88% |

Open issues:

- reasonable restriction of search area

- usage of loop filters

- handling of dual tree

- slice/picture type definition is somewhat unclean

Question: Why is dual tree off better than on for SCC sequences?

Further conclusions under BoG XXXX.

In plenary discussion (Sun): Potential adoption of CPR with current CTU to VTM/VVC

New name?

[JVET-L0077](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4158) CE8: Intra Region-based Template Matching (Test 8.1) [G. Venugopal, K. Müller, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

[JVET-L0290](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4385) CE8: CPR mode with dual-tree support (Test CE8.2) [X. Xu, X. Li, S. Liu (Tencent)]

[JVET-L0293](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4388) CE8: CPR mode with local search ranges (Test CE8.3.1 and CE8.3.2) [X. Xu, X. Li, S. Liu (Tencent)]

[JVET-L0295](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4390) CE8: CPR mode with non local search ranges (Test CE8.3.3, CE8.3.4, CE8.3.5 and CE8.3.6) [X. Xu, X. Li, S. Liu (Tencent)]

[JVET-L0508](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4614) Cross-check report of CE8.3.5 and CE8.3.6 [W. Zhu, A. Segall (Sharp)] [late]

## CE9: Decoder motion vector derivation (15)

Contributions in this category were discussed Friday 5 Oct 1000–1200 (chaired by GJS).

[JVET-L0029](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4340) CE9: Summary report on decoder side motion vector derivation [S. Esenlik, Y.-W. Chen, F. Chen]

The tools in the scope of this CE include template matching and bilateral matching based techniques for motion vector derivation and refinement at the decoder side.

The core experiment summary report is organized into 2 sub-tests as follows:

* CE9.1: Partial Usage of Refined MVs (7 tests)
* CE9.2: DMVR Design (13 tests)
* CE9.2 (Joint tests): (3 tests)

This report summarizes the status of each experiment. Crosscheck results are integrated in the document. There were no tests about BIO.

The software codebase that was used was the release candidate for BMS 2, not the final release, due to delay of the final version software release. This did not seem to cause a problem with the validity of the testing.

Complexity analysis was a significant part of the CE work.

Complexity Assessment of DMVR in BMS2.1

|  |  |
| --- | --- |
| Description of processing steps | 1.a Generate L0 and L1 predictions for [w+4, h+4] blocks (DCTIF) 1.b Calculate block averages 2. perform 9 point MRSAD computation  3.a perform 5 point MRSAD computation  3.b. Generate L0 and L1 half pel predictions for [w+1, h] blocks (DCTIF) 3.c. Generate L0 and L1 predictions for [w, h+1] blocks (DCTIF) 4.a. Perform 2 MRSAD on first half-pel plane 4.b. Perform 2 MRSAD on second half-pel plane 5. Copy final prediction  There are also some alternative ways of implementing the scheme, e.g., increasing the number of sequential steps to save some computations. |
| Data dependency within 128x128 region | none |
| Intermediate Buffers | buffer 1: 2 × (w + 4) × (h + 4) buffer 2: 2 × (w + 1) × h buffer 3: 2 × w × (h + 1)  Altogether that is about 122k bytes if the max size is 128×128.  25 block averages are also stored from step 1.b |
| Usage of refined MVs | Motion compensation and temporal MV prediction  (Not used for deblocking and spatial MV prediction.) |
| Number of operations for interpolation\* | Adds: 10906 Mult: 12464  (including final motion compensation) |
| Number of operations for MRSAD\* | Adds: 4032 |
| Additional operations\* | DMVR application condition: 5 “if” checks MRSAD cost comparisons: 18 comparisons Final MV averaging: 64 additions |
| Smallest block applying DMVR | 4x4 |
| On-chip memory accesses | 1. Read/Write for 1a and 1b 2. Read for 2 3. Read for 3a 4. Read/Write for 3b and 3c 5. Read for 4a and 4b  Total: 5 Reads and 2 Writes (excluding final MC) |
| External memory BW increase (for 8x8 reference blocks) | 60% |

In the discussion, it was commented that it might be better to use the refined motion for deblocking purposes. This would add a line buffering requirement.

*CE9.1: Partial Usage of Refined MVs*

|  |  |  |
| --- | --- | --- |
| **#** | **Description** | **Document numbers** |
| CE9.1.1 | The refined MV is used for de-blocking and temporal MV prediction, and not for spatial prediction. | TBA |
| CE9.1.2 | Refined MV from neighbour CTBs are used in spatial MV prediction (including left, top and top-left CTB). Refined MVs are used for temporal MV prediction and unrefined MV are used for de-blocking. |  |
| CE9.1.3 | Refined MV from top CTB row are used in spatial MV prediction (top and top-left CTB)  Refined MVs are used for temporal MV prediction and unrefined MV are used for de-blocking. |  |
| CE9.1.4 | Refined MV from top CTB row are used in spatial MV prediction (top and top-left CTB).  Refined MVs are used for temporal MV prediction and deblocking. |  |
| CE9.1.5 | (This is, in fact, the same as CE9.1.4)  Refined MV from top CTB row are used in spatial MV prediction (top and top-left CTB).  Refined MVs are used for temporal MV prediction and deblocking. |  |
| CE9.1.6 | Refined MV is used only for MC and original MV is used for MV prediction (spatial and temporal) and deblocking. |  |
| CE9.1.7 | Refined MV from top CTB row are used in spatial MV prediction (top and top-left CTB).  Refined MVs are used for temporal MV prediction (not for deblocking)   * Test a: The MV in previous CU is not marked as unavailable but only unrefined MV can be used and not compressed * Test b: The MV in previous CU is marked as unavailable |  |

As tested, the scheme is only applied when the two referenced pictures bracket the current picture in POC order.

At least one proposed variation (CE2.10) would also enable usage in other cases, using some spatial neighbouring information, and shows some gain in LB and LP (especially LP). This case does not apply biprediction.

Test results for the RA case relative to VTM configuration of BMS release candidate

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **CE Subtest** | **#** | **Y** | **U** | **V** | **EncT** | **DecT** |
| **Subtest 0** | DMVR in BMS2.1 | -1.63% | -1.73% | -1.85% | 104% | 121% |
| **Subtest 1** | CE9.1.1 | -1.66% | -1.72% | -1.85% | 104% | 119% |
| CE9.1.2 | -1.95% | -1.93% | -2.05% | 102% | 120% |
| CE9.1.3 | -1.82% | -1.86% | -1.97% | 103% | 116% |
| CE9.1.4 | -1.86% | -1.89% | -1.99% | 102% | 113% |
| CE9.1.5 | -1.86% | -1.89% | -1.99% | 101% | 117% |
| CE9.1.6 | -1.48% | -1.64% | -1.75% | 104% | 119% |
| CE9.1.7.a | -1.80% | -1.84% | -1.94% | 104% | 120% |
| CE9.1.7.b | -0.87% | -0.79% | -0.86% | 108% | 121% |

SIMD is not used in the achor, but could have been used, and this may explain the decoding time reduction for CE9.1.4.

Combinations with complexity reductions are in other subtest results.

*CE9.2: DMVR Design*

|  |  |  |
| --- | --- | --- |
| **#** | **description** | **Doc #** |
| CE9.2.1 | MRSAD computation on integer samples without interpolation | TBA |
| CE9.2.2 | Reference sample padding applied to eliminate memory extension |  |
| CE9.2.3 | CE9.1.1 and CE9.1.2 combined |  |
| CE9.2.4 | A new search pattern for refinement, 2 step search with 5+5 search points |  |
| CE9.2.5 | Use of parametric error surface for estimation of sub-pixel distance offsets using bilinear interpolation to replace half-pel search |  |
| CE9.2.7 | Early termination for the bilateral matching based on the initial similarity between L-0 and L1 predictions |  |
| CE9.2.8.a | If cross (UP DOWN LEFT RIGHT) check is done and cost of them are all not less than central one, skip the fifth point check for integer |  |
| CE9.2.8.b | Average of the block is calculated based on sub-sampled prediction (use 1 of 4 samples) |  |
| CE9.2.8.c | Use SAD instead of MRSAD |  |
| CE9.2.9.a | Partial MRSAD, calculate MRSAD using every second row of block samples |  |
| CE9.2.9.b | Disable for 4x4 |  |
| CE9.2.9.c | Disable 4x4, 4x8 and 8x4 |  |
| CE9.2.9.d | Disable 4x4, 4x8, 8x4 and 8x8 |  |
| CE9.2.9.e | test a + test b |  |
| CE9.2.9.f | test a + test c |  |
| CE9.2.9.g | test a + test d |  |
| CE9.2.10 | Generate the template with the neighbouring MVs under different test conditions |  |
| CE9.2.11.a | Combine proposed low latency template matching with low latency DMVR |  |
| CE9.2.11.b | Combination of Test a and CE9.2.10 |  |
| CE9.2.12 | Withdrawn |  |
| CE9.2.13.a | * Test early-termination method based on MV difference between merge candidates |  |
| CE9.2.13.b | * Early termination * Bilinear interpolation for search. * Luma 8-tap and 2-tap filters * Chroma 4 tap and 2-tap filters |  |
| CE9.2.13.c | * Early termination * Bilinear interpolation for search. * Luma 8-tap and 4-tap filters * Chroma 4 tap and 2-tap filters |  |
| CE9.2.13.d | * Early termination * Bilinear interpolation for search. * Luma 8-tap, 6-tap and 4-tap filters * Chroma 4 tap and 2-tap filters |  |
| CE9.2.13.e | * Early termination * Bilinear interpolation for search. * Luma 8-tap and 4-tap filters (independent horizontal and vertical decision) * Chroma 4 tap and 2-tap filters (independent horizontal and vertical decision) |  |
| CE9.2.14.a | Bilinear filter is applied for search. 8-tap filter and 4-tap filters for MC |  |
| CE9.2.14.b | 4-tap filter is applied for search. 8-tap and 4-tap filter are applied for MC |  |
| CE9.2.14.c | 6-tap filter is applied for search. 8-tap filter and 6 tap filters are applied for MC |  |

Combination tests

|  |  |
| --- | --- |
| CE9.2.15 | * Combination of 9.2.2, 9.2.7 and 9.2.13. * Disabling for 4x4 * Bilinear interpolation applied for search. * Padding is applied to eliminate memory extension. * Test early-termination method based on MV difference between merge candidates. * Early termination for the bilateral matching based on the initial similarity between L0 and L1 predictions |
| CE9.2.16 | * Combination of 9.2.2, 9.2.7, 9.2.9 and 9.2.13. * Disabling for 4x4, 4x8, 8x4 * Bilinear interpolation applied for search. * Padding is applied to eliminate memory extension. * Test early-termination method based on MV difference between merge candidates. * Early termination for the bilateral matching based on the initial similarity between L0 and L1 predictions * Restrict DMVR to different block sizes. * Calculate SAD for every two rows. |
| CE9.2.6 | Study combinations of CE9.1.4 and CE9.2.5 with CE9.2.16 |

Test results

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **CE Subtest** | **#** | **Y** | **U** | **V** | **EncT** | **DecT** |
| **Subtest 0** | DMVR in BMS2.1 | -1.63% | -1.73% | -1.85% | 104% | 121% |
| **Subtest 2** | CE9.2.1 | -1.39% | -1.53% | -1.61% | 104% | 113% |
| CE9.2.2 | -1.64% | -1.73% | -1.84% | 105% | 118% |
| CE9.2.3 | -1.39% | -1.54% | -1.65% | 104% | 113% |
| CE9.2.4 | -1.63% | -1.70% | -1.83% | 103% | 115% |
| CE9.2.5 | -1.68% | -1.77% | -1.90% | 102% | 109% |
| CE9.2.7 | -1.64% | -1.72% | -1.81% | 103% | 114% |
| CE9.2.8a | -1.64% | -1.73% | -1.82% | 101% | 115% |
| CE9.2.8b | -1.55% | -1.72% | -1.77% | 101% | 112% |
| CE9.2.8c | -1.44% | -1.62% | -1.67% | 101% | 110% |
| CE9.2.9.a | -1.61% | -1.68% | -1.81% | 104% | 115% |
| CE9.2.9.b | -1.64% | -1.75% | -1.87% | 105% | 118% |
| CE9.2.9.c | -1.62% | -1.70% | -1.80% | 103% | 115% |
| CE9.2.9.d | -1.57% | -1.65% | -1.75% | 103% | 115% |
| CE9.2.9.e | -1.61% | -1.70% | -1.85% | 103% | 114% |
| CE9.2.9.f | -1.60% | -1.68% | -1.78% | 103% | 114% |
| CE9.2.9.g | -1.55% | -1.64% | -1.73% | 102% | 112% |
| CE9.2.10 | -0.57% | -0.44% | -0.54% | 108% | 104% |
| CE9.2.10 (LP) | -0.67% | -0.20% | -0.13% | 116% | 106% |
| CE9.2.11-a | -1.76% | -1.81% | -1.96% | 103% | 111% |
| CE9.2.11-b | -2.26% | -2.16% | -2.37% | 117% | 123% |
| CE9.2.13.a | -1.66% | -1.73% | -1.88% | 102% | 117% |
| CE9.2.13.b | -1.29% | -1.40% | -1.41% | 101% | 113% |
| CE9.2.13.c | -1.66% | -1.36% | -1.28% | 101% | 112% |
| CE9.2.13.d | -1.63% | -1.38% | -1.34% | 102% | 114% |
| CE9.2.13.e | -1.68% | -1.56% | -1.57% | 101% | 113% |
| CE9.2.14.a | -1.61% | -1.71% | -1.82% | 103% | 119% |
| CE9.2.14.b | -1.64% | -1.72% | -1.86% | 105% | 121% |
| CE9.2.14.c | -1.63% | -1.74% | -1.84% | 105% | 124% |
| **Combination tests** | CE9.2.15 | -1.65% | -1.74% | -1.88% | 103% | 111% |
| CE9.2.16 | -1.59% | -1.70% | -1.78% | 102% | 110% |
| CE9.2.6 | -1.89% | -1.89% | -2.00% | 101% | 108% |

It was commented that the schemes, as tested, are still not sufficiently mature for adoption into the VTM.

Contribution L0098 proposes approaches that mitigate the memory needed for large blocks, either by disabling for some block sizes or by decomposing large blocks into smaller one. The difference in coding efficiency between those two approaches is about 0.2%. The loss by simply disabling for large blocks is about 0.1%. It was noted that the decomposition approach would generate prediction block edges and should perhaps affect deblocking. Contribution L0382 proposes disabling for large blocks as well.

Further CE study was suggested. The suggested anchor would use the disabling approach from L0098 in combination with CE9.2.6 with block size restricted to disable for block sizes less than w×h=64 luma samples and for block sizes larger than w×h=1024 luma samples.

It was commented that avoiding using a different filter with fractional-sample search rather than the ordinary MC could be undesirable. It was noted that 9.2.1 doesn’t use fractional-sample interpolation in the search at all, so it would not have this issue of using a different filter. That method has a tested loss of about 0.24%. The proponent of that method said they also had some further variation that could avoid that loss (but had not submitted a contribution about it yet).

[JVET-L0163](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4244) CE9: Report on the results of tests CE9.2.15 and CE9.2.16 [S. Esenlik, A. M. Kotra, B. Wang, H. Gao, J. Chen (Huawei), C. Chen, W. Chen, M. Karczewicz (Qualcomm), H. Liu, L. Zhang, K. Zhang (Bytedance), D. Luo, X. Xiu, Y. He, Y. Ye (InterDigital)]

[JVET-L0173](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4264) CE9: Test 9.2.6 (combines CE9.2.15/9.2.16 with elements of 9.1.4 and 9.2.5) [S. Sethuraman (Ittiam)]

[JVET-L0177](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4268) CE9: DMVR Simplifications (Test 9.2.8) [X. Chen, J. Zheng (HiSilicon)]

[JVET-L0178](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4269) CE9: Refined MVs Partial Usage for Spatial (Test 9.1.5) [X. Chen, J. Zheng (HiSilicon)]

[JVET-L0188](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4279) CE9: Unidirectional Template based DMVR and its Combination with Simplified Bidirectional DMVR (Test 9.2.10 and Test 9.2.11) [F. Chen, L. Wang (Hikvision)] [late]

[JVET-L0196](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4287) CE9.2.7 Complexity reduction on decoder-side motion vector refinement (DMVR) [J. Luo, X. Xiu, Y. He, Y. Ye (InterDigital)]

[JVET-L0215](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4306) CE9: Report on the results of tests CE9.1.1, CE9.2.1, CE9.2.2 and CE9.2.3 [S. Esenlik, A. M. Kotra, B. Wang, H. Gao, J. Chen (Huawei)]

[JVET-L0243](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4335) CE9.1.6: DMVR with Constrained Motion Vector Storage [C.-C. Chen, Y. Han, H. Huang, Y. Zhang, C.-H. Hung, W.-J. Chien, M. Karczewicz (Qualcomm)]

[JVET-L0244](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4336) CE9.2.13: MVD-based Early-skip Method and Switchable MC Filters for DMVR [C.-C. Chen, Y. Han, H. Huang, Y. Zhang, C.-H. Hung, W.-J. Chien, M. Karczewicz (Qualcomm)]

[JVET-L0253](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4348) CE9.1.2 Addressing the decoding latency issue for decoder-side motion vector refinement (DMVR) [J. Luo, X. Xiu, Y. He, Y. Ye (InterDigital)]

[JVET-L0254](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4349) CE9.1.3 Addressing the decoding latency issue for decoder-side motion vector refinement (DMVR) [J. Luo, X. Xiu, Y. He, Y. Ye (InterDigital)]

[JVET-L0267](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4362) CE9: Simplification of Decoder Side Motion Vector Derivation (Test 9.2.9) [H. Liu, L. Zhang, K. Zhang, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-L0311](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4406) CE9.1.7: Constrained decoder side motion vector derivation [M. Xu, X. Li, S. Liu (Tencent)]

[JVET-L0312](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4407) CE9.2.14: Interpolation filters in DMVR [M. Xu, X. Li, S. Liu (Tencent)]

## CE10: Combined and multi-hypothesis prediction (18)

Contributions in this category were discussed Friday 5 Oct 1200–XXXX (chaired by GJS).

[JVET-L0030](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4245) CE10: Summary report on combined and multi-hypothesis prediction [C.-W. Hsu, M. Winken, X. Xiu]

A summary of Core Experiment 10 (CE10) on combined and multi-hypothesis prediction is reported. Five sub CEs are created to test different methods of combined predictions, including:

* CE10.1: Multi-hypothesis prediction,
* CE10.2: Overlapped block motion compensation,
* CE10.3: Non-rectangular partitions,
* CE10.4: Diffusion filtering of inter- and intra-prediction signals,
* CE10.5: Multiple affine compensated blocks.

There are 8, 4, 7, 2 and 2 tests for each sub CE, respectively. All tests are evaluated based on the common test conditions defined in JVET-K1010. All tests and crosscheck results are integrated in the summary report.

|  |  |  |  |
| --- | --- | --- | --- |
| Proposal Document # | Corresponding Tests | Author(s) | Title |
| JVET-L0100 | CE10.1.1.a  CE10.1.1.b  CE10.1.1.c  CE10.1.1.d | M.-S. Chiang, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek) | CE10.1.1: Multi-hypothesis prediction for improving AMVP mode, skip or merge mode, and intra mode |
| JVET-L0148 | CE10.1.2.a  CE10.1.2.b  CE10.1.2.c | [M. Winken](mailto:martin.winken@hhi.fraunhofer.de), H. Schwarz, D. Marpe, T. Wiegand (HHI) | CE10: Multi-hypothesis inter prediction (Tests 1.2.a - 1.2.c) |
| JVET-L0385 | CE10.1.3 | [M.-S. Chiang](mailto:man-shu.chiang@mediatek.com), C.-W. Hsu, Y.-W. Huang, S.-M. Lei (Mediatek), [M. Winken](mailto:martin.winken@hhi.fraunhofer.de), H. Schwarz, D. Marpe, T. Wiegand (HHI) | CE10.1.3: Multi-hypothesis prediction |
| JVET-L0101 | CE10.2.1 | Z.-Y. Lin, C.-C. Chen, T.-D. Chuang, C.-Y. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek) | CE10.2.1: OBMC |
| JVET-L0252 | CE10.2.2 | [X. Xiu](mailto:xiaoyu.xiu@interdigital.com), [Y. He](mailto:yuwen.he@interdigital.com),[Y. Yan (InterDigital)](mailto:yan.ye@interdigital.com) | CE10.2.2: Overlapped block motion compensation (OBMC) early termination |
| JVET-L0124 | CE10.3.1.b | [R.-L. Liao](mailto:ruling.liao@sg.panasonic.com), [C. S. Lim (Panasonic)](mailto:chongsoon.lim@sg.panasonic.com) | CE10.3.1.b: Triangular prediction unit mode |
| JVET-L0417 | CE10.3.2.a  CE10.3.2.b  CE10.3.2.c | [M. Bläser](mailto:blaeser@ient.rwth-aachen.de), [J. Sauer (RWTH Aachen University)](mailto:sauer@ient.rwth-aachen.de) | CE10: Results on Geometric Partitioning (Experiments 3.2.a - 3.2.c) |
| JVET-L0125 | CE10.3.3.a  CE10.3.3.b | [Y. Ahn](mailto:yjahn@digitalinsights.co.kr), [D. Sim (Digital Insights)](mailto:dgsim@digitalinsights.co.kr) | CE10: Diagonal motion partitions with uni-prediction constraint (Test 10.3.3) |
| JVET-L0126 | CE10.3.4 | [Y. Ahn](mailto:yjahn@digitalinsights.co.kr), [D. Sim (Digital Insights)](mailto:dgsim@digitalinsights.co.kr), [R.-L. Liao](mailto:ruling.liao@sg.panasonic.com), [C. S. Lim (Panasonic)](mailto:chongsoon.lim@sg.panasonic.com) | CE10: Combined test of CE10.3.1.b and CE10.3.3.b (Test 10.3.4) |
| JVET-L0157 | CE10.4.1  CE10.4.2 | [Jennifer Rasch](mailto:Jennifer.Rasch@hhi.fraunhofer.de),[Anastasia Henkel](mailto:anastasia.henkel@hhi-extern.fraunhofer.de),[Jonathan Pfaff](mailto:Jonathan.pfaff@hhi.fraunhofer.de), [Michael Schaefer](mailto:michael.schaefer@hhi.fraunhofer.de),[Heiko Schwarz](mailto:heiko.schwarz@hhi.fraunhofer.de),[Mischa Siekmann](mailto:mischa.siekmann@hhi.fraunhofer.de),[Philipp Helle](mailto:philipp.helle@hhi.fraunhofer.de),[Martin Winken](mailto:martin.winken@hhi.fraunhofer.de),[Detlev Marpe](mailto:detlev.marpe@hhi.fraunhofer.de),[Thomas Wiegand](mailto:thomas.wiegand@hhi.fraunhofer.de) (HHI) | CE10: Uniform Directional Diffusion Filters For Video Coding |
| JVET-L0269 | CE10.5.1  CE10.5.2 | [K. Zhang](mailto:zhangkai.video@bytedance.com), [L. Zhang](mailto:lizhang.idm@bytedance.com), [H. Liu](mailto:liuhongbin.01@bytedance.com), Y. Wang, P. Zhao, D. Hong (Bytedance) | CE10: Interweaved Prediction for Affine Motion Compensation (Test 10.5.1 and Test 10.5.2) |

*CE10.1: Multi-hypothesis prediction*

In CE10.1, the goal is to test prediction to be combined coming from multiple hypotheses, where one hypothesis refers to prediction from inter mode or from intra mode. The tests and corresponding results are summarized as follows.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Subtest # | Doc # | Supported modes | Hypothesis type | Signalling of hypothesis | # of extra hypotheses | Block constraint in luma samples | BW reduction technique |
| CE10.1.1.a | JVET-L0100 | AMVP (uni-) | inter | merge index | 1 | >= 8x8 |  |
| CE10.1.1.b | JVET-L0100 | skip/merge | inter | merge index (implicitly derived) | 1 or 2 |  | 2 tap MC filter to original luma hypothesis 2 tap MC filter to original chroma hypothesis 2 tap MC filter to additional luma hypothesis 2 tap MC filter to additional chroma hypothesis |
| CE10.1.1.c | JVET-L0100 | merge | intra | mode index | 1 |  |  |
| CE10.1.1.d | JVET-L0100 | skip/merge AMVP (uni-) | intra inter | merge/mode index | 1 or 2 | >= 8x8 | 2 tap MC filter to original luma hypothesis 2 tap MC filter to original chroma hypothesis 2 tap MC filter to additional luma hypothesis 2 tap MC filter to additional chroma hypothesis |
| CE10.1.2.a | JVET-L0148 | merge AMVP (uni-/bi-) | inter | ref index + mvp index + MVDs + weights | 1 or 2 | > 8x8 | 8 tap MC filter to original luma hypothesis 4 tap MC filter to original chroma hypothesis 8 tap MC filter to additional luma hypothesis 4 tap MC filter to additional chroma hypothesis |
| CE10.1.2.b | JVET-L0148 | merge AMVP (uni-/bi-) | inter | ref index + mvp index + MVDs + weights | 1 or 2 | > 8x8 | 8 tap MC filter to original luma hypothesis 4 tap MC filter to original chroma hypothesis 4 tap MC filter to additional luma hypothesis 4 tap MC filter to additional chroma hypothesis |
| CE10.1.2.c | JVET-L0148 | merge AMVP (uni-/bi-) | inter | ref index + mvp index + MVDs + weights | 1 or 2 | > 8x8 | 8 tap MC filter to original luma hypothesis 4 tap MC filter to original chroma hypothesis integer pel MC to additional luma hypothesis integer pel MC to additional chroma hypothesis |
| CE10.1.3 | JVET-L0385 | merge AMVP (uni-/bi-) | intra inter | intra: mode index inter: ref index + mvp index + MVDs + weights | 1 or 2 | >= 8x8 | 8 tap MC filter to original luma hypothesis 4 tap MC filter to original chroma hypothesis 4 tap MC filter to additional luma hypothesis 4 tap MC filter to additional chroma hypothesis |

The following tables summarize the worst case memory bandwidth in terms of required reference samples (luma and chroma) per sample for each test (detailed derivation in the accompanying Excel file):

|  |  |  |  |
| --- | --- | --- | --- |
|  | reference samples/sample | % w.r.t. 4x4 bi-prediction | % w.r.t. 8x8 bi-prediction |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| w | 4 | 8 | 8 | 16 | 16 | 4 | 8 | 8 | 16 | 16 | 4 | 8 | 8 | 16 | 16 |
| h | 4 | 8 | 16 | 8 | 16 | 4 | 8 | 16 | 8 | 16 | 4 | 8 | 16 | 8 | 16 |
| normal (bi-) | 21.4 | 10.1 | 7.8 | 7.8 | 6.0 | 100% | 47% | 36% | 36% | 28% | 212% | 100% | 77% | 77% | 60% |
| additional 2 hypotheses (bi-) |  | 20.2 | 15.6 | 15.6 | 12.0 |  | 94% | 73% | 73% | 56% |  | 200% | 154% | 154% | 119% |
| CE10.1.1.b  CE10.1.1.d |  | 8.2 | 7.6 | 7.6 | 7.0 |  | 38% | 36% | 36% | 33% |  | 81% | 75% | 75% | 70% |
| CE10.1.2.a |  |  | 15.6 | 15.6 | 12.0 |  |  | 73% | 73% | 56% |  |  | 154% | 154% | 119% |
| CE10.1.2.b  CE10.1.3 |  |  | 13.5 | 13.5 | 10.7 |  |  | 63% | 63% | 50% |  |  | 133% | 133% | 106% |
| CE10.1.2.c |  |  | 10.8 | 10.8 | 9.0 |  |  | 51% | 51% | 42% |  |  | 107% | 107% | 89% |

The test results are summarized as follows,

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| # | Config. |  |  | VTM |  |  |
| Y | U | V | EncT | DecT |
| CE10.1.1.a | RA | -0.31% | -0.27% | -0.30% | 109% | 101% |
|  | LB | -0.17% | -0.14% | -0.28% | 110% | 102% |
| CE10.1.1.b | RA | -0.55% | -0.62% | -0.73% | 106% | 104% |
|  | LB | -0.35% | -0.18% | -0.21% | 108% | 103% |
| CE10.1.1.c | RA | -0.51% | -0.41% | -0.50% | 108% | 103% |
|  | LB | -0.50% | -0.90% | -0.83% | 109% | 103% |
| CE10.1.1.d | RA | -1.05% | -1.20% | -1.17% | 115% | 105% |
|  | LB | -0.65% | -0.81% | -0.82% | 118% | 104% |
| CE10.1.2.a | RA | -1.08% | -0.99% | -1.03% | 114% | 102% |
|  | LB | -1.09% | -0.48% | -0.50% | 122% | 104% |
| CE10.1.2.b | RA | -1.03% | -1.00% | -1.03% | 112% | 101% |
|  | LB | -1.00% | -0.49% | -0.41% | 119% | 103% |
| CE10.1.2.c | RA | -0.96% | -0.99% | -1.08% | 109% | 101% |
|  | LB | -1.04% | -0.71% | -0.71% | 113% | 102% |
| CE10.1.3 | RA | -1.39% | -1.31% | -1.32% | 118% | 105% |
|  | LB | -1.35% | -0.97% | -1.07% | 124% | 105% |

Various aspects of complexity issues and memory bandwidth analysis were discussed. Some participants emphasized cache miss analysis.

One topic of focus was CE10.1.1.c (0.5%), which basically performs both intra and inter prediction and blends the two. It was commented that this would basically be free for hardware. In software, it would add complexity.

It was suggested to restrict CE10.1.1.c to w×h >= 64 luma samples and larger block sizes. It was suggested to further discuss this after obtaining test results on the restriction.

Another topic of focus was CE10.1.1.a (0.3%). It was noted that this is just a signalling shortcut that is already supported.

CE10.1.2.c has up to 4 hypotheses. Two of these use integer MVs for luma (maybe half pel for chroma). A weighting combination is signalled by a flag (either x=3/4 on the initial value or x=9/8 on the initial value and 1-x for the additional value). The gain is about 1.0% in RA and LB cases. This feature has already been restricted to to w×h > 64 luma samples and larger block sizes as tested. It was commented that this would use up to 4 different AMVP processes. A test was running with a way to need only two AMVP derivation processes.

It was remarked that there is likely to be some interaction with generalized B (~0.8% for RA).

In further discussion Wed 10 Oct 1130 (GJS), regarding the testing of CE10.1.1.c restriction to w×h >= 64 luma samples and larger block sizes, CTC testing had been completed and text had been provided (L0100) and the results had been cross-checked by Alibaba. The original gain was reportedly 0.51% (RA) and with the restriction, it was reportedly 0.50%, thus no significant impact was observed from the constraint.

The gain of CE10.1.1.c and CE10.1.2.c were reported to be approximately additive (see L0385).

Decision (coding gain): Adopt CE10.1.1.c (described in JVET-L0100) combined intra/inter with restriction to w×h >= 64 luma samples (0.5% in RA).

Further study was suggested for further constraining the block size to w×h <= 1024 luma samples.

In further discussion Wed 10 Oct 1145 (GJS), testing of the above-described variation of CE10.1.2.c was reported in L0679. The complexity analysis included a correction to consider half-pel chroma, which had been neglected in a previous report. The complexity estimate had reportedly been confirmed in private communication. The worst-case memory bandwidth increase w.r.t. 8x8 biprediction was reportedly 21%.

The average decoder impact was reported by analyzing the number of ref. samples per pred. sample, reporting 0 to 24% increase depending on the QP and test sequence category. The average % of CTUs using more than 2 diff. ref. frames was also reported as increasing by 0.5 to 11.1 percentage points. Decoder software for measuring these numbers was provided in L0679.

In L0679, the following modifications were made: Only two AMVP lists are constructed (for the first two inter predictions); for additional hypotheses, one of the those two AMVP lists is used (decision based on the POC difference relative to the picture used in the two initial hypotheses). The degradation resulting from this change was 0.06%, resulting in an overall RA benefit of 0.91% with 9% runtime increase.

It was suggested that, for CUs that use this, OBMC would be not applied (if we have OBMC).

Several participants suggested that study of the cache memory impact is needed. This will be done in CE work. The CE will include an agreed set of cache analysis configurations to be tested.

Initial discussion of the remaining subtests was on Saturday 1530 (GJS).

*CE10.2: Overlapped block motion compensation*

In CE10.2, the goal is to test prediction to be combined from using motions of neighbouring coding units (CUs). The tests and corresponding results are summarized as follows

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | # of blending lines | Blending order | Blending order (sequential/parallel) | BW reduction technique | Runtime reduction technique | Cost reduction technique |
|  |  |  |  |  |  |  |  |
| CE10.2.1 | JVET-L0101 | 2: CTU row boundary 4: otherwise | T & L (CU boundary) | Parallel | Pad right-most column and bottom row reference samples | 1. reuse L shape buffer 2. apply CU size constraints | CTU row buffer reduction |
|  |  |  |  |  |  | 3. remove OBMC flag 4. apply MV merge |  |
| CE10.2.2 | JVET-L0252 | 2: CU area <64 or 4x4 sub CU 4: otherwise | Phase 1 : T->L (CU boundary) | Sequential |  | 1. apply MV merge 2. skip similar MVs |  |
|  |  |  | Phase 2 : T->L->B->R (other sub CU boundaries) |  |  |  |  |
| CE10.2.3.a | JVET-L0255 | 2: CTU row boundary 4: otherwise | T & L (CU boundary) | Parallel | Pad right-most column and bottom row reference samples | 1. reuse L shape buffer 2. apply CU size constraints 3. remove OBMC flag | CTU row buffer reduction |
|  |  |  |  |  |  | 4. apply MV merge 5. skip similar MVs |  |
| CE10.2.3.b | JVET-L0255 | 2: CU area <64 or 4x4 sub CU 4: otherwise | Phase 1 : T->L (CU boundary) | Sequential | Pad reference samples in all directions | 1. reuse L shape buffer 2. apply MV merge | CTU row buffer reduction |
|  |  |  | Phase 2 : T->L->B->R (other sub CU boundaries) |  |  | 3. skip similar MVs |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  | VTM |  |  |
| # | Config. | Y | U | V | EncT | DecT |
| CE10.2.1 | RA | -0.82% | -1.27% | -1.44% | 102% | 108% |
|  | LB | -1.17% | -1.23% | -1.26% | 103% | 109% |
| CE10.2.2 | RA | -1.04% | -1.95% | -2.13% | 106% | 108% |
|  | LB | -1.43% | -2.27% | -2.23% | 108% | 111% |
| CE10.2.3.a | RA | -0.75% | -1.36% | -1.51% | 102% | 105% |
|  | LB | -1.10% | -1.19% | -1.12% | 103% | 104% |
| CE10.2.3.b | RA | -1.02% | -1.82% | -1.94% | 105% | 112% |
|  | LB | -1.43% | -2.02% | -1.98% | 106% | 115% |

Complexity considerations were discussed, aside from runtime.

Discussion focused on 10.2.3.a (not applied for CUs than w×h<64, left and top CU boundary, 4 lines on each side of boundary when w>8 and h>8, 2 lines on CTU row boundaries).

It was commented that there is less gain for the A1 content category. However, it was commented that this may be a matter of the motion characteristics of the particular content rather than an inherent characteristic of high-resolution video. The gain on the A2 category was about 0.75%.

In the JEM, there was a block-level flag for smaller blocks (<256 luma samples) to disable it on a block basis. This was said to be helpful for Class F (any SCC) content. Class F testing was not performed for 10.2.3.a, and the tested scheme did not include a block-level flag.

It was commented that Class F testing was done for CE10.2.1. It was reported that there was no coding efficiency degradation in that test, and a small gain (0.3% for RA, with a mixture of gains and losses for different content).

Draft spec text was not provided.

This was further discussed Wed 10 Oct 1230 (GJS), focusing on CE10.2.3.a (RA gain 0.75%, LB gain 1.10%). A test with the flag had been done and the average difference for having the flag, outside of Class F, was reportedly negligible; in Class F, the gain reported gain was about 0.1-0.2% in RA. In Class F, the gain relative to VTM was 0.3% in RA and 0.2% in LB, with a peak loss of 0.4% for SlideShow versus 0.8% for the non-flag approach.

The contributor said that including the flag might be desirable as a way to avoid potential artefacts in local areas. It was suggested that if we have the flag, there should be a high-level flag (picture level) to indicate whether the low-level flag is present or not.

It was commented that this increases the line buffering by 2 lines at the CTU boundary and increases the number of samples for interpolation by up to 50%. (There are some different ways of trading off bandwidth with line buffering.)

It was suggested to apply OBMC only to uniprediction regions.

Further study in a CE was planned.

*CE10.3: Non-rectangular partitions*

In CE10.3, the goal is to test prediction to be combined from non-rectangular prediction partitions within one CU. The tests and corresponding results are summarized as follows

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | Supported modes | Prediction type | Partitioning | Block constraint in luma samples | BW reduction technique | Note |
|  |  |  |  |  |  |  |  |
| CE10.3.1.b | JVET-L0124 | skip/merge | inter | triangular  (diagonal/inverse diagonal) | >= 8x8 | restricted to uni-prediction |  |
|  |  |  |  |  |  |  |  |
| CE10.3.2.a | JVET-L0417 | merge AMVP | inter intra | geometric (only diagonal/inverse diagonal) | >= 8x8 | restricted to uni-prediction |  |
|  |  |  |  |  |  |  |  |
| CE10.3.2.b | JVET-L0417 | merge AMVP | inter intra | geometric (extended set) | >= 8x8 | restricted to uni-prediction |  |
|  |  |  |  |  |  |  |  |
| CE10.3.2.c | JVET-L0417 | merge AMVP | inter intra | geometric (full set) | >= 8x8 | restricted to uni-prediction |  |
|  |  |  |  |  |  |  |  |
| CE10.3.3.a | JVET-L0125 | merge AMVP | inter | diagonal/inverse diagonal | >= 8x8 && max(W,H) - min(W,H) < 3 | restricted to uni-prediction |  |
|  |  |  |  |  |  |  |  |
| CE10.3.3.b | JVET-L0125 | AMVP | inter | diagonal/inverse diagonal | >= 8x8 && max(W,H) - min(W,H) < 3 | restricted to uni-prediction |  |
|  |  |  |  |  |  |  |  |
| CE10.3.4 | JVET-L0126 | skip/merge AMVP | inter | diagonal/inverse diagonal | skip/merge: >= 8x8 | restricted to uni-prediction | Combined test of 10.3.1.b and 10.3.3.b |
|  |  |  |  |  | AMVP: >= 8x8 && max(W,H) - min(W,H) < 3 |  |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| # | Config. |  |  | VTM |  |  |
|  |  | Y | U | V | EncT | DecT |
| CE10.3.1.b | RA | -0.57% | -0.79% | -0.92% | 110% | 100% |
|  | LB | -1.23% | -1.59% | -1.55% | 110% | 100% |
| CE10.3.2.a | RA | -0.04% | -0.12% | -0.11% | 106% | 114% |
|  | LB | -0.14% | 0.04% | -0.07% | 108% | 110% |
| CE10.3.2.b | RA | -0.04% | -0.09% | -0.14% | 114% | 110% |
|  | LB | -0.15% | -0.15% | -0.19% | 116% | 111% |
| CE10.3.2.c | RA | -0.10% | -0.14% | -0.17% | 162% | 122% |
|  | LB | -0.16% | -0.21% | -0.36% | 220% | 133% |
| CE10.3.3.a | RA | -0.47% | -0.65% | -0.72% | 175% | 103% |
|  | LB | -0.83% | -0.61% | -0.23% | 174% | 99% |
| CE10.3.3.b | RA | -0.27% | -0.38% | -0.42% | 157% | 102% |
|  | LB | -0.49% | -0.32% | -0.29% | 157% | 102% |
| CE10.3.4 | RA | -0.67% | -0.88% | -0.97% | 173% | 101% |
|  | LB | -1.29% | -1.37% | -1.44% | 173% | 101% |

The scheme is applied only to uni-prediction regions.

It was asked what would happen if this and OBMC are both enabled.

It was suggested to focus on CE10.3.1.b. This applies the triangle scheme only to the skip and merge modes.

A related contribution L0208 was reported to have been contributed. The proponent of CE10.3.1.b said that the “bug fix” part of L0208 was certainly desirable.

For MV data storage, the two MVs are stored as if the region was bipredicted.

For deblocking, 4x4 subblocks that cross the diagonal are treated as bipredicted with the two MVs, subblocks that don’t cross the diagonal are treated as unipredicted.

An index indicates which reference pictures to use.

A special derivation logic is used to determine the reference picture candidates.

The encoder impact was 10%, which is substantial. The decoder complexity impact is relatively low.

The interaction with other recent actions, which also affect the same modes, affine and OBMC was unknown. It was noted that further testing will occur even after an adoption (e.g., AHG13) and unfortunate interactions can cause reconsideration.

Class F test results were not provided.

Test results for Class F were requested.

Draft spec text had not been provided.

It was suggested to make Class F mandatory for general CTC. See the notes of the Sunday plenary, at which this was agreed.

This was futher discussed Wednesday 10 October (GJS), focused on CE10.3.1.b. Test results for Class F and draft spec text had been provided in an update of L0124. The draft spec text included the “bug fix” part of L0208, but the added simulation results did not. That aspect was said to have a very small impact on coding efficiency. 0.44% gain was reported in Class F. This gain was primarily not for the SlideShow and SlideEditing sequences. For other classes the average gains were RA 0.57% and LB 1.23%.

It was commented that the encoding time increase may not need to be that high, as further encoding optimization could mitigate the effect. The scheme was applied for blocks of size w×h > 64 samples. It was commented that this implies application to 4x32, which is rather questionable.

It was suggested to consider horizontal and vertical splits (L0208) in addition to diagonal splits, or instead of diagonal splits, which had been agreed to be tested in a CE.

It was asked whether the decision flag would be before or after the combined intra/inter flag. It was agreed that it would be after.

Decision (coding efficiency): Adopt (0.57% in RA, 1.23% in LB), with the L0208 bug fix, flag after combined intra/inter.

Further study whether there is some interference and horizontal and vertical splits and application to AMVP mode (as currently the scheme is for merge mode only) and 4x32 issue and encoder complexity.

*CE10.4: Diffusion filtering of inter- and intra-prediction signals*

In CE10.4, the goal is to test prediction to be combined using filtering, where two types of diffusion filters (uniform and directional) with two iteration parameters are included. The tests and corresponding results are summarized as follows.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | Config. |  |  | VTM |  |  | Description |
|  |  |  | Y | U | V | EncT | DecT |  |
| CE10.4.1 | JVET-L0157 | AI | -0.35% | -0.23% | -0.17% | 152% | 102% | • Fast Encoder Decisions and default restrictions • Additionally sending diffusion parameters in merge case |
|  |  | RA | -0.50% | -0.79% | -0.73% | 125% | 101% | • Low complexity variant • No neighbouring block samples used for inter blocks |
|  |  | LB | -0.18% | 0.12% | 0.02% | 123% | 101% |  |
| CE10.4.2 (new added) | JVET-L0157 | AI | -0.35% | -0.23% | -0.17% | 152% | 102% | • Fast Encoder Decisions and default restrictions • Additionally sending diffusion parameters in merge case |
|  |  | RA | -0.58% | -1.01% | -0.88% | 125% | 101% | • Low complexity variant • Use reconstructed neighbouring sampless for inter blocks |
|  |  | LB | -0.38% | 0.14% | 0.06% | 122% | 100% |  |

This is a filtering applied to the prediction signal – both for intra and inter prediction (although most of the gain is for inter). Four selectable filters may be applied, or no filtering. The ROS has entries in a diamond within a 9x9 region. This is applied only for larger blocks.

The encoding impact is substantial.

Discussed additional possibilities:

* Not applying it for intra prediction
* Reducing the ROS of the filter
* Considering interaction with post-reconstructions filters – whether to use filtered samples or not

*CE10.5: Multiple affine compensated blocks*

In CE10.5, the goal is to test prediction to be combined using multiple affine compensated blocks. The tests and corresponding results are summarized as follows.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | Config. |  |  | VTM |  |  | Description | BW reduction technique |
| Y | U | V | EncT | DecT |
| CE10.5.1 | JVET-L0269 | RA | -0.40% | -0.09% | -0.12% | 101% | 102% | Interweaved prediction for Affine Motion Compensation (AMC) with two different dividing patterns • The second dividing pattern covers the whole current block | restricted to uni-prediction & luma only |
| LB | -0.21% | -0.25% | -0.29% | 103% | 102% |
| CE10.5.2 | JVET-L0269 | RA | -0.35% | -0.08% | -0.14% | 101% | 101% | Interweaved prediction for Affine Motion Compensation (AMC) with two different dividing patterns • The second dividing pattern does not cover the whole current block | restricted to uni-prediction & luma only |
| LB | -0.25% | -0.16% | -0.29% | 102% | 99% |

Affine prediction is performed with an ordinary 4x4 grid and with grid offset by 2 horizontally and vertically. The 2x4 and 4x2 areas at the edges of the block use only one model.

It is only applied to luma, and only applied to uni-prediction.

This is proposed to replace the ordinary uni-predictive affine mode, not to be an alternative encoder mode selection, so in that sense it increases the complexity of any unipredictive affine use.

For test sequences that really contain affine motion, the gain was reported to be larger.

It was commented that the gain may be higher in combination with the new affine merge scheme.

For further study.

[JVET-L0100](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4181) CE10.1.1: Multi-hypothesis prediction for improving AMVP mode, skip or merge mode, and intra mode [M.-S. Chiang, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0101](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4182) CE10.2.1: OBMC [Z.-Y. Lin, C.-C. Chen, T.-D. Chuang, C.-Y. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0124](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4205) CE10.3.1.b: Triangular prediction unit mode [R.-L. Liao, C. S. Lim (Panasonic)]

[JVET-L0463](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4567) Crosscheck of JVET-L0124: CE10.3.1.b Triangular prediction unit mode [M. Bläser (RWTH Aachen University)] [late]

[JVET-L0125](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4206) CE10: Diagonal motion partitions with uni-prediction constraint (Test 10.3.3) [Y. Ahn, D. Sim (Digital Insights)]

[JVET-L0607](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4720) Cross-check of JVET-L0125: CE10.3.3 Diagonal motion partitions with uni-prediction constraint [T. Na, J. Kim (SK Telecom), J. Shin, K. Ko (Pixtree)] [late]

[JVET-L0126](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4207) CE10: Combined test of CE10.3.1.b and CE10.3.3.b (Test 10.3.4) [Y. Ahn, D. Sim (Digital Insights), R.-L. Liao, S. C. Lim (Panasonic)]

[JVET-L0608](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4721) Cross-check of JVET-L0126: Combined test of CE10.3.1.b and CE10.3.3. [T. Na, J. Kim (SK Telecom), J. Shin, K. Ko (Pixtree)] [late]

[JVET-L0148](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4229) CE10: Multi-hypothesis inter prediction (Tests 1.2.a - 1.2.c) [M. Winken, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

[JVET-L0157](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4238) CE10: Uniform Directional Diffusion Filters For Video Coding [J. Rasch, A. Henkel, J. Pfaff, M. Schaefer, H. Schwarz, M. Siekmann, P. Helle, M. Winken, D. Marpe, T. Wiegand (HHI)]

[JVET-L0252](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4347) CE10.2.2: Overlapped block motion compensation (OBMC) early termination [X. Xiu, Y. He, Y. Yan (InterDigital)]

[JVET-L0255](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4350) CE10.2.3: A simplified design of overlapped block motion compensation based on the combination of CE10.2.1 and CE10.2.2 [Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, C.-C. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek), X. Xiu, Y. He, Y. Ye (InterDigital)]

[JVET-L0269](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4364) CE10: Interweaved Prediction for Affine Motion Compensation (Test 10.5.1 and Test 10.5.2) [K. Zhang, L. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-L0479](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4583) Cross-check of JVET-L0269: CE10.5.1 and CE10.5.2 Interweaved Prediction for Affine Motion Compensation [Y. He (InterDigital)] [late] [miss]

[JVET-L0385](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4482) CE10.1.3: Multi-hypothesis prediction [M.-S. Chiang, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (Mediatek), M. Winken, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

[JVET-L0417](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4515) CE10: Results on Geometric Partitioning (Experiments 3.2.a - 3.2.c) [M. Bläser, J. Sauer (RWTH Aachen University)]

## CE11: Deblocking (20)

Contributions in this category were discussed Saturday 6 Oct 1115–1400X (chaired by JRO).

[JVET-L0031](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4247) CE11: Summary report on deblocking [A. Norkin, A. M. Kotra]

This contribution provides a summary report of Core Experiment 11 on deblocking filtering. Three categories of proposals are covered by this CE, split into three sub-tests. These sub-tests are 1) long-tap deblocking filters, 2) general aspects of deblocking filters, and 3) deblocking at 4x4 block boundaries.

The corresponding compression performance of each coding tool evaluated in CE11 is summarized in this contribution. In addition, answers to questions mentioned in [3] [Ed. What’s that?], such as complexity of the proposals and cross-checking results are also provided.

The software basis for this CE was VTM-2.0.1. Configurations and test conditions in JVET-K1010 for SDR sequences are used. Results for additional configuration with ALF turned off are also reported. For the subjective viewing, additional encodes with different QPs have been used.

Sub-CE1: Longer filters

|  |  |  |
| --- | --- | --- |
| **Test** | **Proponent(s)** | **Cross-checker(s)** |
| CE11.1.1 | Kenneth Andersson [kenneth.r.andersson@ericsson.com](mailto:kenneth.r.andersson@ericsson.com)  [JVET-L0072](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4153) | Masaru Ikeda  [Masaru.Ikeda@sony.com](mailto:Masaru.Ikeda@sony.com);  D.Rusanovskyy dmytror@qti.qualcomm.com |
| CE11.1.2 | Kei Kawamura  [ki-kawamura@kddi.com](mailto:ki-kawamura@kddi.com)  [JVET-L0380](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4477) | Woong Il Choi  [woongil.choi@samsung.com](mailto:woongil.choi@samsung.com) |
| CE11.1.3 | Chia-Ming Tsai  [chia-ming.tsai@mediatek.com](mailto:chia-ming.tsai@mediatek.com) [JVET-L0102](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4183) | Hyeongmun Jang  hm.jang@lge.com |
| CE11.1.4 | Dmytro Rusanovskyy  [dmytror@qti.qualcomm.com](mailto:dmytror@qti.qualcomm.com)  [JVET-L0403](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4500) | Kenneth Andersson [kenneth.r.andersson@ericsson.com](mailto:kenneth.r.andersson@ericsson.com) |
| CE11.1.5 | Woong IL Choi [woongil.choi@samsung.com](mailto:woongil.choi@samsung.com)  [JVET-L0062](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4143) | Kei Kawamura  [ki-kawamura@kddi.com](mailto:ki-kawamura@kddi.com) |
| CE11.1.6 | Masaru Ikeda  [masaru.ikeda@sony.com](mailto:masaru.ikeda@sony.com)  [JVET-L0327](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4423) | Kenneth Andersson [kenneth.r.andersson@ericsson.com](mailto:kenneth.r.andersson@ericsson.com) |
| CE11.1.7 | Kiran Misra  [misrak@sharplabs.com](mailto:misrak@sharplabs.com)  [JVET-L0405](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4503) | Masaru Ikeda  [Masaru.Ikeda@sony.com](mailto:Masaru.Ikeda@sony.com)  Adam Wieckowski  adam.wieckowski@hhi.fraunhofer.de |
| CE11.1.8 | Anand Meher Kotra  Anand.meher.kotra@huawei.com  [JVET-L0224](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4315) | Patrice Onno  [patrice.onno@crf.canon.fr](mailto:patrice.onno@crf.canon.fr)  Woong Il Choi  [woongil.choi@samsung.com](mailto:woongil.choi@samsung.com) |
| CE11.1.9 | Kenneth Andersson  [kenneth.r.andersson@ericsson.com](mailto:kenneth.r.andersson@ericsson.com)  [JVET-L0072](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4153) | Christian Helmrich  [christian.helmrich@hhi.fraunhofer.de](mailto:christian.helmrich@hhi.fraunhofer.de) |
| CE11.1.10 | Masaru Ikeda  [masaru.ikeda@sony.com](mailto:masaru.ikeda@sony.com)  Kiran Misra  [misrak@sharplabs.com](mailto:misrak@sharplabs.com)  [JVET-L0140](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4221) | Anand Meher Kotra  [anand.meher.kotra@huawei.com](mailto:anand.meher.kotra@huawei.com) |
| CE11.1.11 | Kenneth Andersson  [kenneth.r.andersson@ericsson.com](mailto:kenneth.r.andersson@ericsson.com)  [misrak@sharplabs.com](mailto:misrak@sharplabs.com)  [JVET-L0337](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4434) | Jie Zhao  [jie.zhao@lge.com](mailto:jie.zhao@lge.com) |

|  |  |  |
| --- | --- | --- |
| **Tests** | **Luma modified (Y/N)** | **Chroma modified (Y/N)** |
| CE11.1.1 | Y | N |
| CE11.1.2 | Y | N |
| CE11.1.3 | Y | N |
| CE11.1.4 S1 | Y | N |
| CE11.1.4 S2 | Y | N |
| CE11.1.5 | Y | N |
| CE11.1.6 | Y | Y |
| CE11.1.7 S1 | Y | Y |
| CE11.1.7 S2 | Y | Y |
| CE11.1.8 | Y | N |
| CE11.1.9 | Y | Y |
| CE11.1.10 | Y | Y |
| CE11.1.11 | Y | Y |

11.1.1 and 11.1.9 use longer filters for 16x16 blocks or larger. They use 5 samples at each side for 16x16 boundaries, and 5 or 7 samples for 32x32 or larger; the other proposals apply stronger deblocking only for any side >=32. Some proposals switch between different filter length depending on conditions such as sample differences over block boundary or at both sides. Conceptually similar to VTM deblocking, but typically taking more samples into account. Characteristics are in table below:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Tests** | **Samples from block bound. modified** | **Samples from block bound. deblocking decision** | **Max num. oper for filtering per line (add/mult/compar/shift)** | **Max number of oper. for decision for 8-sample boundary (add/mult/compar/shift)** | **Num. line buffers** |
| VTM2.0.1 | 3+3 | 4+4 | 56 (28/2/12/14) | 94 per 8 line segment | 4 |
| CE11.1.1 | 7+7, 5+5 | 16 | 120 (46,24,28,22) | 30 (15,0,13,2) per line for 32x32 blocks\* 8  = + 240 op | 8 |
| CE11.1.2 | 7+7 | 7+7 | 246 (138, 12, 28, 68) | 20(10,0,6,4) per 4 line segment\* 2 segments  = + 20 op | 8 |
| CE11.1.3 | 7+7, 7+4, 4+7, 4+4 | 16 | 266 (168, 34, 28, 36) | 25 (12,0,11,2) per line | 8 |
| CE11.1.4 S1 | 4+4/4+3 | 6+6/6+4 | 123 (56/39/0/28) | 32(20/0/2/10) per line\*4 = + 120op | 6 |
| CE11.1.4 S2 | 4+4/4+3 | 6+6/6+4 | 123 (56/39/0/28) | 32(20/0/2/10) per line\* 4  = + 128 op | 6 |
| CE11.1.5 | 7+7, 3+7 | 16 | 190(124/12/0/54) | 5(3/0/1/1) per line\* 4  = + 20 op | VTM |
| CE11.1.6 | 7+7 | 16 | 146 (104,0,28,14) | 48(25,0,14,9) per line\* 4  =+ 192 op | 8 |
| CE11.1.7 S1 | 7+7, 7+3, 3+7 | 16, 12 | 97\* (55, 0, 28, 14) | Worst case is same as HEVC.  20 (11, 0, 5, 4) \* 4  = + 80 op | 8 |
| CE11.1.7 S2 | 7+7, 7+3, 3+7 | 16, 12 | 97\* (55, 0, 28 14) | Worst case is same as HEVC.  20 (11, 0, 5, 4) per line\*4  = + 80 op | 8 |
| CE11.1.8 | 7+7,  3 + 7 for hor. edges between CTUs | 16 | 142(96/4/0/42) | 20(14, 2,2,2) per line  \* 4 lines = + 80 op | VTM |
| CE11.1.9 | 7+7, 5+5 | 16 | 120 (46,24,28,22) | 30 (15,0,13,2) per line for 32x32 blocks\* 8  = + 240 op | 8 |
| CE11.1.10 | 7+7, 7+3, 3+7 | 16, 12 | 97\* (55, 0, 28, 14) | Worst case is same as HEVC.  20 (11, 0, 5, 4) per line\*4  = + 80 op | 8 |
| CE11.1.11 | 7+7, 7+3, 3+7 | 16, 12 | 120 (46,24,28,22) | Worst case is same as HEVC.  20 (11, 0, 5, 4) per line\*4  = + 80 op | 8 |

Note: In the table above, CE11.1.1/9 are listed for 32x32 case. It is verbally reported to have less worst-case operation count for 16x16 blocks. Generally, none of the proposals exceeds the worst case of VTM which would be the case when all 8x8 boundaries need to be deblocked.

Objective results:

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **AI** | | | | | **RA** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.1.1 | 0.0% | 0.0% | 0.0% | 106%\* | 99% | 0.0% | 0.0% | -0.1% | 99% | 100% |
| CE11.1.2 | 0.2% | 0.0% | 0.0% | 100% | 101% | 0.1% | 0.0% | 0.0% | 100% | 101% |
| CE11.1.3 | 0.0% | 0.0% | 0.0% | 100% | 101% | 0.0% | 0.0% | 0.0% | 100% | 103% |
| CE11.1.4 S1 | 0.2% | 0.0% | 0.0% | 100% | 100% | -0.2% | -0.1% | -0.3% | 99% | 100% |
| CE11.1.4 S2 | 0.0% | 0.0% | 0.0% | 99% | 100% | -0.1% | -0.1% | -0.2% | 99% | 100% |
| CE11.1.5 | 0.0% | 0.0% | 0.0% | 100% | 100% | 0.0% | 0.0% | -0.1% | 100% | 100% |
| CE11.1.6 | 0.0% | -0.7% | -0.6% | 100% | 102% | -0.1% | -1.2% | -1.1% | 100% | 103% |
| CE11.1.7 S1 | 0.0% | 1.0% | 1.3% | 102% | 102% | 0.2% | 1.0% | 1.1% | 100% | 102% |
| CE11.1.7 S2 | 0.0% | 0.4% | 0.4% | 102% | 102% | 0.2% | 0.3% | 0.3% | 100% | 102% |
| CE11.1.8 | 0.0% | 0.0% | 0.0% | 100% | 102% | 0.0% | 0.0% | 0.0% | 99% | 101% |
| CE11.1.9 | 0.0% | -0.6% | -0.6% | 103%\* | 103% | 0.0% | -1.8% | -2.1% | 98%\* | 104% |
| CE11.1.10 | 0.0% | -0.7% | -0.6% | 100% | 100% | 0.1% | -1.1% | -1.2% | 99% | 103% |
| CE11.1.11 | 0.0% | -0.4% | -0.4% | 103% | 102% | 0.3% | -0.4% | -0.4% | 96% | 104% |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **LD-B** | | | | | **LD-P** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.1.1 | 0.0% | 0.0% | -0.1% | 101% | 100% | 0.0% | 0.1% | 0.2% | 102%\* | 101% |
| CE11.1.2 | 0.1% | -0.1% | -0.1% | 100% | 101% | 0.1% | 0.0% | 0.2% | 100% | 101% |
| CE11.1.3 | 0.0% | -0.1% | -0.1% | 100% | 102% | 0.0% | 0.1% | 0.1% | 100% | 102% |
| CE11.1.4 S1 | -0.2% | -0.3% | -0.4% | 99% | 101% | -0.2% | -0.4% | -0.1% | 100% | 101% |
| CE11.1.4 S2 | -0.1% | -0.2% | -0.4% | 99% | 101% | -0.1% | -0.3% | -0.1% | 100% | 102% |
| CE11.1.5 | 0.1% | 0.0% | -0.2% | 100% | 100% | 0.1% | 0.0% | 0.2% | 100% | 101% |
| CE11.1.6 | -0.1% | -1.5% | -1.7% | 96% | 101% | -0.1% | -1.7% | -1.7% | 100% | 104% |
| CE11.1.7 S1 | 0.5% | 0.5% | 0.4% | 100% | 102% | 0.3% | 0.8% | 0.8% | 100% | 102% |
| CE11.1.7 S2 | 0.4% | 0.3% | 0.0% | 100% | 102% | 0.3% | 0.3% | 0.4% | 102% | 103% |
| CE11.1.8 | 0.1% | -0.1% | -0.3% | 100% | 100% | 0.0% | 0.1% | 0.1% | 100% | 100% |
| CE11.1.9 | -0.1% | -2.0% | -2.1% | 101% | 105% | -0.1% | -2.2% | -2.0% | 100% | 104% |
| CE11.1.10 | 0.3% | -1.5% | -1.4% | 96% | 103% | 0.2% | -1.5% | -1.5% | 100% | 101% |
| CE11.1.11 | 0.4% | -0.2% | -0.1% | 99% | 101% | 0.3% | 0.1% | 0.0% | 100% | 98% |

For subjective results, see JVET-L0611 below.

BoG (A. Segall) to further analyse the results of subjective test in L0611, identify if it is possible to conclude that visual improvement over VTM (ALF off) has been achieved, and if there is consistency that certain proposals perform better. If necessary, additional expert viewing.

Also review CE related documents on longer deblocking

See further notes under L0681.

Sub-CE2: General aspects of deblocking

|  |  |  |
| --- | --- | --- |
| **Test** | **Proponent(s)** | **Cross-checker(s)** |
| CE11.2.1: derivation of tC table values | Christophe Gisquet  [christophe.gisquet@crf.canon.fr](mailto:christophe.gisquet@crf.canon.fr)  [JVET-L0192](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4283) | Anand Meher Kotra  [anand.meher.kotra@huawei.com](mailto:anand.meher.kotra@huawei.com)  Biao Wang: biao.wang@huawei.com |
| CE11.2.2: QP offset for deblocking depending on the average luma values | Atsuro Ichigaya  [ichigaya.a-go@nhk.or.jp](mailto:ichigaya.a-go@nhk.or.jp)  [JVET-L0414](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4512) | Anand Meher Kotra  [anand.meher.kotra@huawei.com](mailto:anand.meher.kotra@huawei.com)  Biao Wang: biao.wang@huawei.com |

Objective results (ALF off):

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **AI** | | | | | **RA** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.2.1 S1 | 0.0% | -0.1% | 0.2% |  |  | 0.0% | -2.1% | -2.2% |  |  |
| CE11.2.1 S2 | -0.3% | -0.5% | -0.3% |  |  | 0.0% | -0.8% | -0.6% |  |  |
| CE11.2.1 S3 | -0.2% | -0.5% | -0.3% |  |  | 0.1% | -0.4% | -0.4% |  |  |
| CE11.2.1 S4 | -0.3% | -0.3% | 0.0% |  |  | 0.3% | -0.7% | -0.6% |  |  |
| CE11.2.1 S5 | -0.3% | -0.1% | 0.3% |  |  | 0.0% | -2.3% | -2.2% |  |  |
| CE11.2.1 S6 | -0.3% | -0.5% | -0.1% |  |  | 0.0% | -2.6% | -2.5% |  |  |
| CE11.2.2 S1 | 0.0% | 0.0% | 0.0% | 100% | 99% | 0.0% | -0.1% | 0.0% | 100% | 99% |
| CE11.2.2 S2 | 0.1% | 0.0% | 0.0% | 100% | 99% | 0.0% | 0.0% | 0.0% | 100% | 100% |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **LD-B** | | | | | **LD-P** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.2.1 S1 | 0.0% | -1.6% | -1.6% |  |  | -0.1% | -2.0% | -2.2% |  |  |
| CE11.2.1 S2 | -0.1% | -0.3% | -0.3% |  |  | 0.1% | 0.1% | -0.1% |  |  |
| CE11.2.1 S3 | -0.1% | 0.0% | 0.0% |  |  | 0.2% | -0.2% | 0.2% |  |  |
| CE11.2.1 S4 | 0.0% | -0.2% | 0.0% |  |  | 0.6% | -0.1% | 0.3% |  |  |
| CE11.2.1 S5 | -0.2% | -1.6% | -1.6% |  |  | 0.1% | -2.0% | -1.8% |  |  |
| CE11.2.1 S6 | -0.2% | -1.3% | -1.5% |  |  | 0.0% | -2.2% | -2.1% |  |  |
| CE11.2.2 S1 | 0.0% | -0.1% | -0.1% | 99% | 101% | 0.0% | 0.0% | 0.0% | 99% | 101% |
| CE11.2.2 S2 | 0.1% | 0.0% | 0.0% | 100% | 102% | 0.0% | 0.2% | 0.1% | 100% | 101% |

Objective (ALF on):

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **AI** | | | | | **RA** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.2.1 S1 | 0.0% | -0.7% | -0.5% |  |  | 0.0% | -1.7% | -1.8% |  |  |
| CE11.2.1 S2 | -0.4% | -0.6% | -0.4% |  |  | -0.1% | -0.6% | -0.6% |  |  |
| CE11.2.1 S3 | -0.3% | -0.6% | -0.4% |  |  | -0.1% | -0.4% | -0.3% |  |  |
| CE11.2.1 S4 | -0.3% | -0.6% | -0.4% |  |  | 0.1% | -0.7% | -0.5% |  |  |
| CE11.2.1 S5 | -0.4% | -0.8% | -0.5% |  |  | -0.2% | -1.8% | -1.9% |  |  |
| CE11.2.1 S6 | -0.4% | -1.0% | -0.8% |  |  | -0.2% | -2.3% | -2.4% |  |  |
| CE11.2.2 S1 | 0.0% | 0.0% | 0.0% |  | 98% | 0.0% | 0.1% | -0.1% |  | 99% |
| CE11.2.2 S2 | 0.1% | 0.0% | 0.0% |  | 98% | 0.1% | 0.0% | -0.1% |  | 98% |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **LD-B** | | | | | **LD-P** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.2.1 S1 | -0.1% | -1.9% | -2.1% |  |  | -0.1% | -1.9% | -1.8% |  |  |
| CE11.2.1 S2 | -0.2% | -0.3% | -0.3% |  |  | -0.2% | -0.2% | -0.2% |  |  |
| CE11.2.1 S3 | -0.2% | -0.4% | -0.2% |  |  | -0.2% | -0.3% | -0.3% |  |  |
| CE11.2.1 S4 | -0.2% | -0.4% | -0.2% |  |  | 0.0% | -0.2% | -0.1% |  |  |
| CE11.2.1 S5 | -0.3% | -2.0% | -1.9% |  |  | -0.3% | -2.0% | -1.9% |  |  |
| CE11.2.1 S6 | -0.3% | -1.8% | -1.9% |  |  | -0.3% | -1.9% | -1.9% |  |  |
| CE11.2.2 S1 | 0.0% | -0.1% | -0.1% |  | 98% | 0.0% | 0.0% | 0.3% |  | 98% |
| CE11.2.2 S2 | 0.1% | 0.2% | -0.1% |  | 97% | 0.1% | 0.0% | 0.2% |  | 99% |

CE11.2.1.S1 is disabling filtering the chroma boundary if luma is not filtered

CE11.2.1.S2 are changing tc offset table to make it better suitable for 10bit (S3/S4 are for 8 bit). S5 combines S1&S2, S6 is an additional filter operation on top of S5. Objective gains are in same range.

For subjective tests, see L0611 below. Subjectively, not possible to identify a clear advantage.

Further study was recommended on the possible need to change the tc mechanism.

CE11.2.2 is also changing the qp offset locally based on average luma value. Objectively, no gain. The S2 version applies the method everywhere, whereas S1 has a different mapping table which uses it more in bright area. Subjectively (from L0611) the method is in the upper range (first quarter of participants) for all sequences, with some cases non-overlapping confidence interval, distinguishable from the anchor.

Decision: Adopt JVET-L0414. Other from the proposal, which makes the QP offset dependent on transfer function, the values shall be signalled in the SPS. Default is not applying (enabling flag=0). If the flag is 1, another syntax element follow indicating the number of intervals (2 bits for 2,3,4,5), and then the luma threshold values and QP offsets between the intervals.

The specification text was later confirmed by B. Bross to be deemed acceptable.

CE11.3: Deblocking of 4x4 block boundaries

|  |  |  |
| --- | --- | --- |
| **Test** | **Proponent(s)** | **Cross-checker(s)** |
| CE11.3.1 | Kenneth Andersson [kenneth.r.andersson@ericsson.com](mailto:kenneth.r.andersson@ericsson.com)  [JVET-L0073](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4154) | Dmytro Rusanovskyy  [dmytror@qti.qualcomm.com](mailto:dmytror@qti.qualcomm.com) |
| CE11.3.2 | Kenneth Andersson [kenneth.r.andersson@ericsson.com](mailto:kenneth.r.andersson@ericsson.com)  [JVET-L0074](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4155) | Chia-Ming Tsai  [chia-ming.tsai@mediatek.com](mailto:chia-ming.tsai@mediatek.com) |
| CE11.3.3 | Anand Meher Kotra Anand.meher.kotra@huawei.com  [JVET-L0225](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4316) | Kiran Misra [misrak@sharplabs.com](mailto:misrak@sharplabs.com) |
| CE11.3.4 | Chia-Ming Tsai  chia-ming.tsai@mediatek.com  [JVET-L0103](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4184) | Kenneth Andersson  [kenneth.r.andersson@ericsson.com](mailto:kenneth.r.andersson@ericsson.com) |
| CE11.3.5 | Hyeongmun Jang  hm.jang@lge.com  [JVET-L0170](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4261) | Chia-Ming Tsai  [chia-ming.tsai@mediatek.com](mailto:chia-ming.tsai@mediatek.com) |

(include PSNR results from L0031)

Organize an expert viewing which identifies whether the approaches of 4x4 deblocking show visual advantage over VTM (ALF off). This includes 3.1, 3.3, 3.4, 3.5. Ideally, it should be possible to get some ranking or verify the outcome of L0611.

BoG (A. Kotra) to further analyse the proposals on 4x4 grid deblocking in terms of complexity (including decision mechanisms which block boundaries can be deblocked such that parallel processing is still possible). The possible interaction with CE11.2.2 shall also be investigated.

Also review CE related documents on 4x4 deblocking.

See further notes under L0681.

It is generally noted that it may be beneficial to include HDR test cases in upcoming deblocking investigations.

[JVET-L0611](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4724) Subjective assessment of CE11 proposals [V. Baroncini, A. Norkin, A. M. Kotra] [late]

This contribution provides a report of the subjective test for the proposals in Core Experiment 11 on deblocking filtering. The test was performed before the Macao meeting according with the CE11 description document JVET-K1031.

[JVET-L0062](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4143) CE11: Test results of CE11.1.5 long-tap deblocking filter [W. Choi, K. Choi (Samsung)]

[JVET-L0072](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4153) CE11: Long deblocking filters for luma (CE11.1.1) and for both luma and chroma (CE11.1.9) [K. Andersson, Z. Zhang, R. Sjöberg (Ericsson)]

[JVET-L0073](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4154) CE11: Non-recursive deblocking of luma on 4x4 grid (CE11.3.1) [K. Andersson, Z. Zhang, R. Sjöberg (Ericsson)]

[JVET-L0074](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4155) CE11: Deblocking of sub-block boundaries for luma (CE11.3.2) [K. Andersson, Z. Zhang, R. Sjöberg (Ericsson)]

[JVET-L0102](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4183) CE11.1.3: Long deblocking filters [C.-M. Tsai, T.-D. Chuang, C.-W. Hsu, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0103](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4184) CE11.3.4: Parallel deblocking for 4 x N and N x 4 block boundaries [C.-M. Tsai, C.-W. Hsu, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0140](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4221) CE11: Combination of CE11.1.6 and CE11.1.7 (CE11.1.10) [W. Zhu, K. Misra, P. Cowan, A. Segall (Sharp), M. Ikeda, T. Suzuki (Sony)]

[JVET-L0170](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4261) CE11.3.5 Parallel deblocking filter [H. Jang, J. Nam, S. Kim, J. Lim (LGE)]

[JVET-L0192](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4283) CE11: Higher precision modification for VVC deblocking filter (Test 2.1) [C. Gisquet, P. Onno, G. Laroche, J. Taquet (Canon)]

[JVET-L0224](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4315) CE11.1.8 Longer tap luma deblocking filter [A. M. Kotra, B. Wang, S. Esenlik, H. Gao, Z. Zhao, J. Chen (Huawei)]

[JVET-L0225](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4316) CE11.3.3 Deblocking for 4 x N and N x 4 block boundaries [A. M. Kotra, S. Esenlik, B. Wang, H. Gao, Z. Zhao, J. Chen (Huawei)]

[JVET-L0327](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4423) CE11: Long-tap deblocking filter for luma and chroma (CE11.1.6) [M. Ikeda, T. Suzuki (Sony)]

[JVET-L0337](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4434) CE11.1.11: Combination of CE11.1.1 and CE11.1.7 [W. Zhu, K. Misra, P. Cowan, A. Segall (Sharp), K. Andersson, Z. Zhang, R. Sjöberg (Ericsson)]

[JVET-L0380](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4477) CE11: Extended Deblocking Filter (CE11.1.2) [K. Unno, K. Kawamura, S. Naito (KDDI)]

[JVET-L0398](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4495) Cross-check of CE11.1.11 [J. Zhao, S. Kim (LGE)] [late]

[JVET-L0403](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4500) CE11: Test on long deblocking filtering from JVET-J0021/K0334 (CE11.1.4) [D. Rusanovskyy, M. Karczewicz (Qualcomm)]

[JVET-L0405](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4503) CE11: Deblocking modifications for Large CUs both luma and chroma (Test 11.1.7a and CE11.1.7b) [W. Zhu, K. Misra, P. Cowan, A. Segall (Sharp)]

[JVET-L0414](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4512) CE11: Luma-adaptive deblocking filter (CE11.2.2) [A. Ichigaya, S. Iwamura, S. Nemoto (NHK)]

## CE12: Mapping functions (8)

Contributions in this category were discussed Friday 5 Oct 1950–2130 (chaired by JRO).

[JVET-L0032](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4248) CE12: Summary report on mapping functions [E. François, D. Rusanovskyy, P. Yin]

This contribution provides a summary report of Core Experiment 12 on mapping functions. CE12 aims at evaluating approaches for mapping of HDR and SDR content. The considered technologies are out-of-loop dynamic range adaptation, in-loop reshaping, in-loop cross-component chroma refinement. Test results against VTM2.0.1 anchors are provided for each performed test. Crosschecking reports are integrated in this contribution.

* HDR-related
  + CE12-1: out-of-loop dynamic range adaptation (JVET-K0298/JVET-L0205)
  + CE12-2: in-loop reshaping for HDR (JVET-K0308/JVET-L0245)
  + CE12-3: in-loop chroma refinement for HDR (JVET-K0298/JVET-L0206)
* SDR-related
  + CE12-4: in-loop reshaping for SDR (JVET-K0309/JVET-L0246)
  + CE12-5: in-loop chroma refinement for SDR (JVET-K0468/JVET-L0206)
* CE12-related in-loop reshaping
  + JVET-L0247: CE12-related: Universal low complexity reshaper for SDR and HDR video
    - * Results tested in CE (CE12-2.1a2 / CE12-4)
  + CE12-related out-of-loop reshaping
  + JVET-L0490: CE12-related: HDR Coding with Backward Compatibility Options

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **All Intra** |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | Test# | DE100 | PSNRL100 | wPsnrY | wPsnrU | wPsnrV | psnrY | psnrU | psnrV | EncT | DecT |
| out-of-loop mapping | DRA+K0298+QPHARM+REFLC | 12-1.1 | -6.4% | -4.0% | -2.0% | -8.4% | -20.1% | 2.0% | -1.1% | -10.7% | 99% | 102% |
|  | DRA+K0308+QPHARM+REFLC | 12-1.2 | -7.5% | -2.9% | -2.3% | -9.5% | -21.0% | -0.3% | -2.7% | -12.1% | 101% | 102% |
| in-loop mapping | ILM+K0308+ILFOPT3 | 12-2.1a1 | 1.5% | -2.4% | -2.0% | 2.7% | 1.3% | 0.0% | 8.4% | 7.9% | 104% | 100% |
|  | ILM+K0308+ILFOPT0 | 12-2.1a2 | 1.4% | -2.0% | -1.7% | 2.8% | 1.2% | 0.1% | 8.4% | 7.8% | 100% | 101% |
|  | ILM+K0298+ILFOPT3 | 12-2.1b | 2.8% | -3.6% | -1.7% | 4.0% | 1.8% | 2.3% | 10.1% | 8.6% | 103% | 102% |
|  | ILM+K0308+ILFOPT3+QPHARM | 12-2.2 | 1.2% | -2.4% | -2.0% | 1.9% | 0.9% | 0.1% | 7.1% | 7.4% | 103% | 102% |
|  | ILM+K0308+ILFOPT3+ILREFC | 12-2.3a | -0.4% | -2.4% | -2.0% | -2.9% | -9.0% | 0.1% | 2.6% | -1.7% | 102% | 102% |
|  | ILM+K0308+ILFOPT3+ILREFLC | 12-2.3b | -0.6% | -2.5% | -2.3% | -2.9% | -9.0% | -0.4% | 2.6% | -1.7% | 104% | 98% |
| in-loop refint | ILREFC | 12-3. | -2.4% | 0.0% | 0.1% | -6.2% | -11.3% | 0.1% | -5.9% | -10.2% | 97% | 100% |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Random** | **Access** |  |  |  |  |  |  |  |  |  |  |  |
|  |  | Test# | DE100 | PSNRL100 | wPsnrY | wPsnrU | wPsnrV | psnrY | psnrU | psnrV | EncT | DecT |
| out-of-loop mapping | DRA+K0298+QPHARM+REFLC | 12-1.1 | -8.4% | -4.8% | -2.6% | -6.0% | -24.4% | 1.7% | 1.6% | -14.7% | 99% | 107% |
|  | DRA+K0308+QPHARM+REFLC | 12-1.2 | -9.0% | -3.0% | -2.5% | -6.5% | -24.8% | -0.5% | 0.6% | -15.4% | 100% | 108% |
| in-loop mapping | ILM+K0308+ILFOPT3 | 12-2.1a1 | 2.5% | -2.3% | -2.1% | 5.0% | 6.3% | -0.2% | 10.6% | 12.6% | 103% | 104% |
|  | ILM+K0308+ILFOPT0 | 12-2.1a2 | 2.3% | -2.0% | -1.8% | 4.8% | 5.5% | -0.1% | 10.3% | 11.8% | 101% | 103% |
|  | ILM+K0298+ILFOPT3 | 12-2.1b | 3.2% | -3.6% | -2.2% | 5.3% | 6.3% | 1.2% | 11.1% | 12.7% | 101% | 106% |
|  | ILM+K0308+ILFOPT3+QPHARM | 12-2.2 | 2.4% | -2.3% | -2.1% | 4.2% | 5.8% | -0.2% | 9.6% | 12.0% | 102% | 106% |
|  | ILM+K0308+ILFOPT3+REFC | 12-2.3a | 0.8% | -2.3% | -2.1% | 1.3% | -0.9% | -0.1% | 7.0% | 6.4% | 101% | 106% |
|  | ILM+K0308+ILFOPT3+REFLC | 12-2.3b | 0.8% | -2.3% | -2.2% | 1.3% | -1.0% | -0.2% | 7.0% | 6.4% | 100% | 100% |
| in-loop refint | ILREFC | 12-3. | -1.8% | 0.0% | 0.0% | -4.1% | -7.4% | 0.0% | -3.7% | -6.3% | 103% | 102% |

No viewing during meeting, but proponents of in/out loop approaches performed mutual crosschecks and confirmed that

* Both in-loop and out-of-loop outperform the anchors objectively
* No subjective visual difference between in-loop and out-of-loop
* CE12-1.2 and CE12-2.3.b perform similarly for wPSNRY (HDR) (AI diff 0.0%, RA diff 0.3%)
* CE12-1.2 outperforms CE12-2.3.b for wPsnrU/V, DE100, and PSNR L100.

The out-of-loop reshaping shows same (or objectively higher) benefit than in-loop, and both are claimed to outperform the anchors. It would be premature at the current status of standardization to define the correct place of signalling (as HL syntax is just starting to be developed). However, it might be useful to be used as anchor in the future after confirmation of subjective benefit. Possibility of subjective viewing prior to next meeting to be identified.

CE12.4: In-loop reshaping for SDR

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **All Intra** | Test# | psnrY | psnrU | psnrV | EncT | DecT |
| in-loop mapping | 12-4. | -1.0% | 2.6% | 2.1% | 107% | 105% |
| in-loop refint | 12-5. | 0.0% | −1.1% | −0.9% | 101% | 100% |
|  |  |  |  |  |  |  |
| **Random Access** | Test# | psnrY | psnrU | psnrV | EncT | DecT |
| in-loop mapping | 12-4. | −1.3% | 2.1% | 1.6% | 106% | 105% |
| in-loop refint | 12-5. | 0.0% | −1.3% | −1.0% | 101% | 101% |

Inverse reshaping is generally done before the loop filter, and motion comp is applied in the original domain. This means that in the decoding process, reshaping is applied after motion comp, inverse reshaping after adding the residual. The same is applied in intra and inter prediction for inter slices. At the decoder, the inverse reshaping must be performed for each block after reconstruction. After computing the prediction in the original domain, it must be reshaped such that the residual can be added.

At the encoder, the original is once reshaped as whole picture, and then the decoder in the encoder loop has to perform the process above (reshaping of prediction, inverse reshaping of reconstruction).

Both reshaping and inverse reshaping are LUT operations, only applied for luma. Additionally, the chroma residual is scaled depending on the luma.

In case of RA, intra slice is not reshaped for UHD, as it was found that the reshaped signal increases the rate for QP 22 significantly. In case of AI, reshaping is done to the entire picture, prediction and coding are performed in reshaped domain, and inverse reshaping before loop filters

In the encoder for RD decision, weighted PSNR is used.

Some of the PSNR curves are crossing. Generally, the gain is becoming lower at higher rates.

It is generally that the reshaped version has higher rate than the anchor, so the quality of B pictures is likely better than the anchor, while the I picture should be the same.

The gain is highly sequence dependent, highest gain for Marketplace (5.2%).

Several aspects require further study:

* Implementation, regarding the impact on pipelining of the block-wise prediction loop, dependency between luma and chroma, etc., interdependency with CCLM
* investigate performance in low QP range, to see if quality saturates
* Since the quality difference of I vs B pictures is changed, and rate allocation is spatially varying impact on visual quality (compared to anchors at lower bit rate points). Informal viewing to be announced.

Viewing was done Monday. Experts who participated did not observe visual differences, such that it can be judged that the method does not produce visual artifacts.

Further investigate in a CE the behaviour at different (and also lower) QP. Currently, the same reshaping function was used for QP points. Investigate the possibility to make it rate adaptive, or disable towards higher rates.

It is also inconsistent that for AI the reshaping was done at the picture level (before in-loop filtering), and for RA not at all in I slices in UHD sequences. This should be unified. Cases should also be studied (in RA) where the rate for the inter pictures stays similar as in CTC.

CE12-5 applies an additional in-loop filter (not a block-wise operation as in CE12.4) to the chroma component after the deblocking filter. This is a cross-component operation, sample-wise scaling of the chroma values depending on the luma value. The mapping function used for scaling is a piecewise linear function, which is designed in a way (and signalled per frame) such that the chroma values are coming closer to the original. For SDR, this results in chroma gains of around 1%, obviously no luma gain. Overall, the bit rate reduction (or PSNR improvement) seems to be very low. It would also require 2-pass coding to determine the LUT. No benefit for in-loop operation.

CE12 will continue on the investigation of using mapping functions for SDR content. E. François and P. Yin to coordinate the CE description. The HDR viewing prior to next meeting (mentioned somewhere else in context of HDR AHG) will further investigate the subjective benefit of in-loop and out-loop reshaping for HDR content, to identify possible necessary actions.

[JVET-L0205](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4296) CE12: report of CE12-1 on out-of-loop dynamic range adaptation [E. François, C. Chevance, F. Hiron (Technicolor), D. Rusanovskyy, A. K. Ramasubramonian, M. Karczewicz (Qualcomm)]

[JVET-L0206](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4297) CE12: report of CE12-3 and CE12-5 on in-loop refinement [E. François, C. Chevance, F. Hiron (Technicolor)]

[JVET-L0245](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4337) CE12-2: HDR In-loop Reshaping [T. Lu, F. Pu, P. Yin, W. Husak, S. McCarthy, T. Chen (Dolby)]

[JVET-L0246](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4338) CE12-4: SDR In-loop Reshaping [F. Pu, T. Lu, P. Yin, W. Husak, S. McCarthy, T. Chen (Dolby)]

[JVET-L0633](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4746) Cross-check of JVET-L0246: CE12-4 related: Additional results of encoder-only lumaDQP approach [R. Vanam (InterDigital)] [late]

## CE13: Coding tools for 360° omnidirectional video (21)

Contributions in this category were discussed XXday XX Oct XXXX–XXXX (chaired by XXX).

[JVET-L0033](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4249) CE13: Summary report on coding tools for 360° omnidirectional video [P. Hanhart, J.-L. Lin, C. Pujara]

[JVET-L0075](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4156) CE13: Hybrid Cubemap with Pre-rotation (Test 6.2) [C. Pujara, A. Konda, A. Singh, R. Gadde, W. Choi, K. Choi, K. P. Choi(Samsung)]

[JVET-L0211](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4302) CE13: Results on CE13.3.2, CE13.4.3 and CE13.7.7 [J. Sauer, M. Bläser (RWTH Aachen University)

[JVET-L0228](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4319) CE13: HEC with 8 samples padding around face row (Test 1.1.a) [P. Hanhart, Y. He, Y. Ye (InterDigital)]

[JVET-L0229](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4320) CE13: HEC with intra prediction disabled across face discontinuities (Test 2.1) [P. Hanhart, Y. He, Y. Ye (InterDigital), C.-H. Shih, J.-L. Lin, C.-C. Ju (MediaTek)]

[JVET-L0230](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4321) CE13: HEC with face row based geometry padding using projection with bilinear interpolation (Test 3.1.b) [P. Hanhart, Y. He, Y. Ye (InterDigital)]

[JVET-L0231](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4322) CE13: PERP with horizontal geometry padding of reference pictures (Test 3.3) [P. Hanhart, Y. He, Y. Ye (InterDigital)]

[JVET-L0232](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4323) CE13: HEC with deblocking and ALF disabled across face discontinuities (Test 4.1.c) [P. Hanhart, Y. He, Y. Ye (InterDigital)]

[JVET-L0233](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4324) CE13: HEC with adaptive frame packing (Test 6.1) [P. Hanhart, Y. He, Y. Ye (InterDigital)]

[JVET-L0234](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4325) CE13: Combined test 7.5 [P. Hanhart, Y. He, Y. Ye (InterDigital)]

[JVET-L0235](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4326) CE13: Combined test 7.6 [P. Hanhart, Y. He, Y. Ye (InterDigital)]

[JVET-L0236](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4327) CE13: Combined test 7.8.b [P. Hanhart, Y. He, Y. Ye (InterDigital)]

[JVET-L0345](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4442) CE13: Intra prediction using spherical neighbours (Test 2.2) [C.-H. Shih, J.-L. Lin, H.-C. Lin, S.-K. Chang, Y.-C. Chang, C.-C. Ju (MediaTek)]

[JVET-L0346](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4443) CE13: Face row based geometry padding of reference pictures (Test 3.1.a and Test 3.1.c) [C.-H. Shih, J.-L. Lin, H.-C. Lin, S.-K. Chang, Y.-C. Chang, C.-C. Ju (MediaTek)]

[JVET-L0347](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4444) CE13: De-blocking filter disabled across face discontinuities (Test 4.1.a) [S.-Y. Lin, J.-L. Lin, H.-C. Lin, S.-K. Chang, Y.-C. Chang, C.-C. Ju (MediaTek)]

[JVET-L0348](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4445) CE13: In-loop filters disabled across face discontinuities (Test 4.1.b and Test 4.1.d) [S.-Y. Lin, L. Liu, J.-L. Lin, H.-C. Lin, S.-K. Chang, Y.-C. Chang, C.-C. Ju (MediaTek)]

[JVET-L0349](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4446) CE13: In-loop filters using spherical neighbours (Test 4.2) [S.-Y. Lin, L. Liu, J.-L. Lin, H.-C. Lin, S.-K. Chang, Y.-C. Chang, C.-C. Ju (MediaTek)]

[JVET-L0350](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4447) CE13: Padding and in-loop filters disabled across face discontinuities (Test 7.1) [S.-Y. Lin, L. Liu, J.-L. Lin, S.-K. Chang, Y.-C. Chang, C.-C. Ju (MediaTek)]

[JVET-L0351](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4448) CE13: Intra prediction and in-loop filters disabled across face discontinuities, and unfolding-based padding (Test 7.3 and 7.4) [C.-H. Shih, S.-Y. Lin, L. Liu, J.-L. Lin, S.-K. Chang, Y.-C. Chang, C.-C. Ju (MediaTek)]

[JVET-L0352](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4449) CE13: Intra prediction and in-loop filters using spherical neighbours, and geometry padding (Test 7.8.a) [C.-H. Shih, S.-Y. Lin, L. Liu, J.-L. Lin, S.-K. Chang, Y.-C. Chang, C.-C. Ju (MediaTek)]

[JVET-L0422](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4521) CE13: In-loop filters disabled across face discontinuities and post-filtering of seam artifacts (Test 7.2.a) [X. Huangfu, Y. Sun, L. Yu (Zhejiang Univ.)] [late]

## CE14: Post-reconstruction filtering (5)

Contributions in this category were discussed Saturday 6 Oct 1530–1700 (chaired by JRO).

[JVET-L0034](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4250) CE14: Summary report on post-reconstruction filtering [L. Zhang, S. Ikonin]

This contribution provides a summary report of Core Experiment 14 on post-reconstruction filtering methods. The techniques are evaluated according to BD-rate gain, complexity (in both encoder and decoder).

The software basis for the mandatory test in this CE is BMS-2.0.1, for VTM based comparisons the BMS software is configured to produce VTM-2.0.1. For the optional test, BMS-2.1 is used as the anchor with BMS tools enabled. Test sequences, configurations and test conditions are according to JVET-K1010 [1] for SDR.

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 14.1.a | Bilateral filter turning off the filtering for 4x4 intra and inter blocks. No LUT – linear model | [JVET-L0172](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4263) |
| 14.1.b | Bilateral filter turning off the filtering for 4x4, 4x8 and 8x4 intra/inter blocks. No LUT – linear model. | [JVET-L0172](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4263) |
| 14.1.c | Bilateral filter with LUT rows consisting of more than 16  8-bit values (provided as reference). Turned off for 4x4. | [JVET-L0172](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4263) |
| 14.2.a | In-loop bilateral filter (also operated after block reconstruction,  i.e. affecting subsequent intra prediction),  weights presented with piece-wise linear model (PWL), 10 ranges (pieces)  not applied to blocks with 4x4, and not applied to inter blocks with min(W, H)>8 | [JVET-L0406](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4504) |
| 14.2.b | In-loop bilateral filter (also operated after block reconstruction,  i.e. affecting subsequent intra prediction),  weights presented with PWL, 2 ranges (pieces)  not applied to blocks with 4x4, and not applied to inter blocks with min(W, H)>8 | [JVET-L0406](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4504) |
| 14.2.c\* | In-loop bilateral filter (also operated after block reconstruction,  i.e. affecting subsequent intra prediction),  weights presented with PWL, 2 ranges (pieces)  not applied to blocks with 4x4, and not applied to inter blocks with min(W, H)>16, similar to tests 14.1 and 14.3 | [JVET-L0406](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4504)  /JVET-L0584 |
| 14.3a | Hadamard Transform Domain Filter with LUT 140 bytes, not applied to 4x4 block, applied for intra and inter | [JVET-L0326](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4422) |
| 14.3b | Hadamard Transform Domain Filter with LUT size 70 bytes, not applied to 4x4 block, applied for intra and inter | [JVET-L0326](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4422) |

It was suggested that additional information be added to the CE summary which is a kind of table indicating with checkmarks for which cases which technology is applied in intra and inter.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Test | filter shape | Comp. complex. per sample\* | Precis. of mult | Parallel friendly | Latency  (in clock cycles) | Memory. required  (bytes) | How to derive filter coeffs | Min. and max. filtered  CU size |
| 14.1.a | 5 pixel “plus”-shape;  For inter, 5x5 area is used to calculate filter weights. | Intra:  4 mult 9 adds 4 checks  Inter:  4 mult 23 adds 10 checks | Intra:  9×8 and 12×9  Inter:  9×8 and 12×11 | yes | At very high clock freq: Intra:10  Inter:  11  Estimation at lower clock freq: 3-4 clock cycles. | 63 | Intra:  Inter: | Min:  4x8, 8x4  Max:  Intra: 64x64  Inter: 16x64, 64x16 |
| 14.1.b | —”— | —”— | —”— | —”— | —”— | —”— | —”— | Min: 8x8  Max: same as  14.1.a |
| 14.2.a,  LUT based | 5 pixel “plus”-shape  Inter:  w(x) with NL average | Intra: 2 mult 8 adds 2 checks  Inter: 2 mult  18 ads  5 checks | 32 bits registers | yes | Intra: 2  Inter: 3 | ROM: 120  CU level: <370\*2 | Computed prior to CU: | Min:  4x8, 8x4  Max:  Intra: 64x64  Inter: 8x64, 64x8 |
| 14.2.b  LUT based | —”— | —”— | —”— | —”— | —”— | ROM: 120  CU level: <210\*2 | Computed prior to CU: | —”— |
| 14.2.c  LUT based | —”— | —”— | —”— | —”— | —”— | —”— | —”— | Min:  4x8, 8x4  Max:  Intra: 64x64  Inter: 16x64, 64x16 |
| 14.2.a\*\*  LUT Free | —”— | Intra: 4 mult 12 adds 13 checks  Inter: 4 mult 22 ads  16 checks | 32 bits registers | yes | Intra: 4  Inter: 5 | ROM: 120  CU level: 24 |  | —”— |
| 14.2.b\*\* LUT free | —”— | Intra: 4 mult 12 adds 4 checks  Inter: 4 mult 22 ads  7 checks | —”— | —”— | Intra: 3  Inter: 4 | ROM: 120   CU level: 10 |  | —”— |
| 14.2.c \*\*  LUT free | —”— | —”— | —”— | —”— | —”— | —”— | —”— | Min:  4x8, 8x4  Max:  Intra: 64x64  Inter: 16x64, 64x16 |
| 14.3.a | 3x3 | 0 mult 20 adds + 4 1-bit add for rounding 6 checks | n/a | yes | 1 clock:  @770MHz 16nm  @450MHz 28nm 2 clocks:  @770MHz 28nm | 140  (32 7-bit values per qp group) | Precalculated in LUT | Min:  4x8 and 8x4  Max:  Intra: 64x64  Inter: 16x64 or 64x16 |
| 14.3.b | —”— | —”— | —”— | —”— | —”— | 70  (16 7-bit values per qp group) | —”— |  |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **AI** | | | | | **RA** | | | | | **LDB** | | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 14.1.a | -0.39% | 0.12% | 0.16% | 103% | 105% | -0.67% | -0.10% | -0.14% | 105% | 102% | -0.64% | 0.59% | 0.39% | 103% | 103% |
| 14.1.b | -0.30% | 0.09% | 0.11% | 105% | 103% | -0.58% | -0.10% | -0.10% | 105% | 102% | -0.64% | 0.45% | 0.51% | 105% | 101% |
| 14.1.c \* | -0.42% | 0.14% | 0.18% | 105% | 104% | -0.71% | -0.05% | -0.11% | 104% | 103% | -0.75% | 0.30% | 0.38% | 103% | 104% |
| 14.2.a | -0.43% | 0.20% | 0.18% | 113% | 110% | -0.60% | -0.12% | -0.07% | 87%\*\* | 83%\*\* | -0.75% | 0.2% | 0.03% | 103% | 101% |
| 14.2.b | -0.42% | 0.13% | 0.16% | 114% | 108% | -0.59% | -0.13% | -0.11% | 93%\*\* | 103% | -0.75% | 0.37% | 0.03% | 104% | 102% |
| 14.2.c | -0.42% | 0.13% | 0.16% | 108% | 109%\* | -0.71% | -0.21% | -0.17% | 106%\* | 110%\* | -0.71% | 0.48% | 0.38% | 92%\*\* | 103% |
| 14.3.a | -0.48% | 0.28% | 0.31% | 109% | 110% | -0.70% | -0.14% | -0.19% | 105% | 104% | -0.68% | 0.40% | 0.67% | 104% | 104% |
| 14.3.b | -0.47% | 0.28% | 0.32% | 109% | 110% | -0.70% | -0.17% | -0.06% | 105% | 104% | -0.66% | 0.14% | 0.31% | 103% | 104% |

The most interesting technologies are 14.1a and 14.3b. These are directly competing technologies. Both have roughly same compression gain, and similar increase in encoding/decoding time. What might be of more concern (and might also lead to a decision adopting none of them) is the complexity added at a critical position in the decoding, which could cause latency issues in particular for intra coding. A detailed analysis on this shall be performed, documenting worst case number of operations, cycles, also including the possibility that a different LUT may need to be used for the Hadamard filter for each next CU if the QP is switched to a different range. SIMD complexity aspects should also be addressed.

BoG (L. Zhang) to further investigate, and also look into CE-related contributions.

The issue was raised that the post-reconstruction filters cause an additional complexity problem in requiring inverse transform for RD decision at the encoder. However, as the filters are not requiring low-level signalling, they could be disabled at high level without causing additional rate cost, such that any encoder could choose using them or not.

[JVET-L0172](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4263) CE14: Reduced latency, LUT-free bilateral filter [J. Ström, P. Wennersten, J. Enhorn, D. Liu, K. Andersson, R. Sjöberg]

[JVET-L0326](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4422) CE14: Hadamard transform domain filter (Test 3) [S. Ikonin, V. Stepin, D. Kuryshev, J. Chen (Huawei)]

[JVET-L0636](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4749) CE14: Crosscheck of CE14.3 (JVET-L326) [J. Ström, P. Wennersten, J. Enhorn, D. Liu, K. Andersson, R. Sjöberg (Ericsson)] [late]

The crosscheckers have confirmed BD-rate results for CE14.3a and CE14.3b (JVET-L0326). Runtimes have also been investigated and are found to be matching. A code review has also taken place, especially investigating the look-up table used to approximate the transfer function used to filter the Hadamard coefficients. The crosscheckers claim that this results in discontinuities in the transfer function. They further claim that this leads to quantization effects in intensity ramps. The updated version (JVET-L0656) has also been investigated. The crosscheckers claim that this leads to similar quantization effects. The contributors are asked to investigate if some of this effect are becoming visible in video sequences (or images). May it be a problem [clarify]

[JVET-L0406](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4504) CE14: Test on in-loop bilateral filter from JVET-J0021/JVET-K0384 with parametrization (CE14.2) [D. Rusanovskyy, N. Shlyakhov, M. Karczewicz (Qualcomm)]

## CE15: Palette mode (3)

Contributions in this category were discussed Saturday 6 Oct 1700–1830 (chaired by JRO).

[JVET-L0035](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4517) CE15: Summary report on palette mode [Y.-C. Sun, Y.-H. Chao, X. Xu]

The following tests in table 1 are performed in CE15.

Table 1: tests that are evaluated and studied in this CE.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Test** | **Tester** | **Document** | **Tool description** | **Cross checker** |
| 15.1 | Yu-Chen Sun (Alibaba) Yung-Hsuan Chao (Qualcomm) | JVET-K0411 | Palette mode in JVET-K0411 | J. Ye (Tencent) |
| 15.2 | Yung-Hsuan Chao (Qualcomm) Yu-Chen Sun (Alibaba) | HEVC-SCC | Palette mode in HEVC-SCC | Jianqing Zhu (Fujitsu) |

CE15.1 and CE15.2 share the same software code base and can be switched by macro setting. The difference between two tests are summarized in table 2.

|  |  |  |
| --- | --- | --- |
|  | **CE15.1** | **CE15.2** |
| **Index map coding** | 1. Raster scan 2. Escape mode is coded in INDEX mode 3. Palette Index is signaled (TBC) 4. PLT index(bypass), run type(CABAC), run length(CABAC), and escape sample (bypass) are coded in interleaved manner 5. Escape sample is coded using TBC (QP dependent) 6. Escape sample: encode Y/ Cb / Cr together for each escape sample | 1. Horizontal / Vertical traverse scan (flag) 2. Escape mode is coded in INDEX/COPY\_ABOVE mode 3. Redundancy removal before signalling index (TBC) : if previous pixel is INDEX: curIDX prevIDX if previous pixel is COPY\_ABOVE: curIDX aboveIDX 4. Encode PLT index (bypass) for whole CU  -> run type (CABAC) and run length (CABAC) interleaved -> escape samples for whole CU (bypass) 5. Escape sample is coded with Exponential-Golomb coding 6. Encode Y for whole CU -> Cb for whole CU -> Cr for whole CU. |
| **Syntax inference** | 1. Signal palette info regardless of palette table size | 1. If palette table size <= 1:  PLT index = 0 run type = INDEX scanning: horizontal run length = number of pixels in the CU if palette table size > 1:  signalling palette info |
| **Bug fix** |  | 1. Bug fix in escape sample coding: fix the issue in division (only affect low QP) |

The results of the CE15.1 and CE15.2 software released Sep. 17 are denoted as “15.1” and “15.2”. Later, the proponents provided an encoding-only update, and the results are denoted as “15.1\*” and “15.2\*. The software with encoding only change is updated roughly 12 hours after the deadline (PST). The anchor is BMS-2.0.1 with VTM cfg.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra Main 10** | |  |  |  |
|  |  | **VTM\_config** | |  |  |  |
|  | **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CTC overall | 15.1 | 0.11% | 0.12% | 0.11% | 111% | 104% |
| 15.2 | 0.09% | 0.12% | 0.11% | 111% | 102% |
| 15.1\* | 0.11% | 0.12% | 0.11% | 104% | 99% |
| 15.2\* | 0.09% | 0.13% | 0.12% | 108% | 104% |
| Class F | 15.1 | -10.27% | -7.97% | -7.95% | 122% | 92% |
| 15.2 | -11.51% | -9.19% | -9.23% | 122% | 96% |
| 15.1\* | -10.27% | -7.97% | -7.99% | 116% | 91% |
| 15.2\* | -11.52% | -9.23% | -9.20% | 119% | 96% |
| SCC 1080p | 15.1 | -30.44% | -25.20% | -25.23% | 138% | 70% |
| 15.2 | -33.48% | -28.20% | -28.24% | 130% | 68% |
| 15.1\* | -30.44% | -25.18% | -25.22% | 132% | 68% |
| 15.2\* | -33.48% | -28.20% | -28.25% | 129% | 67% |

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| --- | --- | --- | --- | --- | --- | --- |
|  |  | **Random Access Main 10** | | |  |  |
|  |  | **VTM\_config** | |  |  |  |
|  | **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CTC overall | 15.1 | 0.12% | 0.08% | 0.11% | 110% | 102% |
| 15.2 | 0.11% | 0.10% | 0.16% | 113% | 102% |
| 15.1\* | 0.13% | 0.16% | 0.16% | 106% | 100% |
| 15.2\* | 0.17% | 0.26% | 0.23% | 107% | 103% |
| Class F | 15.1 | -7.95% | -7.33% | -7.76% | 117% | 99% |
| 15.2 | -8.89% | -8.33% | -8.76% | 114% | 97% |
| 15.1\* | -7.80% | -7.21% | -7.63% | 107% | 95% |
| 15.2\* | -8.72% | -8.07% | -8.63% | 108% | 98% |
| SCC 1080p | 15.1 | -14.56% | -13.46% | -13.17% | 124% | 92% |
| 15.2 | -17.06% | -16.01% | -15.69% | 122% | 88% |
| 15.1\* | -13.93% | -12.76% | -12.45% | 100% | 88% |
| 15.2\* | -16.44% | -15.30% | -14.99% | 101% | 88% |

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|  |  | **Low Delay B Main 10** | | |  |  |
|  |  | **VTM\_config** | |  |  |  |
|  | **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CTC overall | 15.1 | 0.17% | 0.06% | -0.04% | 112% | 103% |
| 15.2 | 0.11% | 0.20% | -0.11% | 112% | 103% |
| 15.1\* | 0.15% | 0.10% | -0.12% | 105% | 101% |
| 15.2\* | 0.13% | 0.18% | -0.07% | 108% | 103% |
| Class F | 15.1 | -4.77% | -4.08% | -4.89% | 117% | 105% |
| 15.2 | -5.67% | -5.07% | -6.25% | 112% | 100% |
| 15.1\* | -4.46% | -3.18% | -4.18% | 107% | 100% |
| 15.2\* | -5.22% | -4.71% | -5.88% | 105% | 100% |
| SCC 1080p | 15.1 | -6.42% | -6.17% | -5.56% | 123% | 100% |
| 15.2 | -8.94% | -8.89% | -8.21% | 121% | 96% |
| 15.1\* | -6.00% | -5.79% | -5.01% | 98% | 94% |
| 15.2\* | -8.64% | -8.59% | -7.77% | 100% | 94% |

For CTC (camera-content video), some small loss occurs. This is somehow expected as it is known that palette mode is not matching the properties of natural video.

It is pointed out that 15.2 is different from HEVC, as it uses separate palette for luma and chroma in intra slices (when dual tree is enabled), whereas HEVC-SCC uses a combined palette. This is however necessary, as dual tree enforces different CU shapes.

Additional results were shown in a powerpoint presentation (v4 of L0035) that additonal gain (approx. 1% for RA) is possible when enabling separate trees also for inter slices. It is requested to submit those results as a CE related contribution.

Why is it necessary to simplify palette compared to HEVC? At CU level, HEVC palette mode is not the most complex element. However, in hardware it requires additional building blocks separate from the other elements. In mobile applications, the saving of computing power when palette is invoked may be interesting as well.

At the current status, it would be premature to adopt a tool that has specific advantage only for screen content to VVC. 15.2 might be a good candidate for BMS, if it would still exist. Otherwise, it shall be used as reference in the upcoming CE cycle. The continuing CE shall provide results both with and without CPR enabled (same reference version as used in CE8). Several experts had the opinion that the version with separate trees for inter should be a better reference. This should be further discussed along with the aforementioned CE related contribution.

Aspect to be discussed in plenary: How much effort should we currently put into tools that mainly have advantage for screen content?

Additional results combined with CPR (from BMS)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra Main 10** | |  |  |  |
|  |  | **VTM\_config** | | | | |
|  | **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** |
| Class F | 8.3.1a (curCTU) | -11.61% | -11.82% | -11.87% | 155% | 102% |
| 15.1 | -10.27% | -7.97% | -7.95% | 122% | 92% |
| 15.2 | -11.51% | -9.19% | -9.23% | 122% | 96% |
| 15.1 + 8.3.1a (curCTU) | -14.51% | -13.10% | -13.21% | 169% | 94% |
| 15.2 + 8.3.1a (curCTU) | -15.33% | -14.05% | -14.14% | 168% | 94% |
| SCC 1080p | 8.3.1a (curCTU) | -36.51% | -35.89% | -36.20% | 148% | 99% |
| 15.1 | -30.44% | -25.20% | -25.23% | 138% | 70% |
| 15.2 | -33.48% | -28.20% | -28.24% | 130% | 68% |
| 15.1 + 8.3.1a (curCTU) | -43.27% | -39.84% | -40.03% | 157% | 75% |
| 15.2 + 8.3.1a (curCTU) | -44.65% | -41.13% | -41.32% | 155% | 73% |

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| --- | --- | --- | --- | --- | --- | --- |
|  |  | **Random Access Main 10** | | |  |  |
|  |  | **VTM\_config** | | | | |
|  | **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** |
| Class F | 8.3.1a (curCTU) | -9.63% | -9.93% | -9.88% | 115% | 102% |
| 15.1 | -7.95% | -7.33% | -7.76% | 117% | 99% |
| 15.2 | -8.89% | -8.33% | -8.76% | 114% | 97% |
| 15.1 + 8.3.1a (curCTU) | -11.36% | -11.21% | -11.23% | 126% | 101% |
| 15.2 + 8.3.1a (curCTU) | -12.04% | -11.86% | -12.15% | 128% | 102% |
| SCC 1080p | 8.3.1a (curCTU) | -22.76% | -22.82% | -23.10% | 110% | 97% |
| 15.1 | -14.56% | -13.46% | -13.17% | 124% | 92% |
| 15.2 | -17.06% | -16.01% | -15.69% | 122% | 88% |
| 15.1 + 8.3.1a (curCTU) | -25.54% | -24.91% | -24.82% | 123% | 94% |
| 15.2 + 8.3.1a (curCTU) | -26.86% | -26.21% | -26.10% | 124% | 93% |

Palette mode gives still additional gain when combined with CPR. Its standalone gain is smaller than the standalone gain of CPR.

[JVET-L0336](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4432) CE15-2: Palette mode of HEVC SCC [Y.-H. Chao, H. Wang, V. Seregin, M. Karczewicz (Qualcomm), Y.-C. Sun, J. An, J. Lou (Alibaba)]

[JVET-L0344](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4441) CE15-1: Palette mode [Y.-C. Sun, J. An, J. Lou (Alibaba), Y.-H. Chao, H. Wang, V. Seregin, M. Karczewicz (Qualcomm)]

# Non-CE Technology proposals

## CE1 related – Partitioning (28)

Contributions in this category were discussed Saturday 6 Oct 1830–2200 (chaired by JRO) except noted otherwise.

[JVET-L0050](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4131) CE1-related: Split Constraint Considering Picture Boundary Condition [M. W. Park, M. Park, K. Choi (Samsung)]

Was reviewed in BoG JVET-L0658

[JVET-L0452](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4554) Crosscheck of JVET-L0050 (CE1-related: Split Constraint Considering Picture Boundary Condition) [Y. Zhao (Huawei)] [late]

[JVET-L0051](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4132) CE1-related: Partitioning Clean-ups [M. Park, M. W. Park, K. Choi (Samsung)]

This contribution proposes two modifications of the partitioning structure in VVC. One is to remove the adaptive signalling of the maximum binary tree size from the slice header, and the other is to set the maximum binary and ternary tree sizes to the possible maximum sizes by default. The first clean-up reportedly shows –0.08% BD-rate with 107% encoding time on RA. When an encoder optimization technique is applied on top of the first clean-up, the result reportedly shows 0.02% BD-rate with 99% encoding time. The second clean-up reportedly shows –0.57% BD-rate with 140% encoding time on AI, –0.12% BD-rate with 105% encoding time on RA. When an encoder optimization technique is applied on top of the second clean-up, the results reportedly show –0.05% for Y, –0.87% for U and –0.86% for V BD-rates with 102% encoding time on AI, and –0.01% for Y, –0.39% for U and –0.35% for V BD-rates with 101% encoding time on RA. Results of two clean-ups with the encoder optimization techniques reportedly show –0.05% for Y, –0.87% for U and –0.86% for V BD-rates with 102% encoding time on AI, and 0.02% for Y, –0.37% for U and –0.33% for V BD-rates with 99% encoding time on RA.

Removal is not a good option, as encoders can use this beneficially (e.g. if they don’t use the maximum depth in their checks).

It is furthermore requested to use identical maximum depth for intra and inter slices, and for intra and inter. By increasing the maximum depth for intra slices, the above mentioned gain of approx. 0.6% (at 140% encoding time) is achieved (“second cleanup”), but loss for RA.

The encoder optimization technique reduces the runtime, but the gain is almost gone.

The current signalling of VVC allows signalling the max size of binary split only for inter, whereas it is fixed to 32 for luma and 64 for chroma. The proposal shows that compression benefit is possible by increasing the value to 64 for luma as well (which is not the same for inter, where it is 128). Allowing a maximum BT size 64 for luma in intra slices seems desirable, whereas CTC should stay with 32 (to avoid increase of runtime). Another proposal (L0218) requests such a signalling.

Currently, the max size of ternary split is fixed to 32 for intra, 64 for inter. The proposal requests changing it from 32 to 64 for intra; as it would be desirable to retain 32 for CTC, it would be necessary to define a signalling mechanism for max ternary tree split size as well. This signalling is not requested in this proposal, and no results are available for this.

No action on this specific proposal.

[JVET-L0485](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4589) Cross-check of JVET-L0051: CE1-related: Partitioning Clean-ups [J. Ma (HHI)] [late]

[JVET-L0063](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4144) CE1-related: Split Unit Coding Order [Y. Piao, J. Chen, A. Tamse, M. Park, K. Choi, K. P. Choi (Samsung)]

This contribution presents split unit coding order (SUCO) proposed in CfP response JVET-J0024. SUCO allows referring to not only left but also right reconstructed pixels and right coded information at leaf node by supporting more flexible coding order at split unit. A split unit (SU) which is further partitioned into quad-tree or vertically partitioned into Bi- or Triple- tree can be either coded from left to right (L2R) or right to left (R2L) by a flag indicating the coding order. CU-level intra prediction and inter prediction tools which utilize left information previously need to be extended accordingly to the right for more efficient coding based on the availability of neighbourhood. The simplest configuration of SUCO provides 0.5% BD-rate gain in AI and 0.6% BD-rate gain in RA configuration on VTM2.0.

The current results show significant increase in encoder runtime (200% and higher) to achieve the gain mentioned above. It is also reported that the current implementation might still have a bug.

Further study necessary for better tradeoff

[JVET-L0585](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4696) Crosscheck of JVET-L0063 (CE1-related: Split Unit Coding Order) [Y. Zhao (Huawei)] [late]

[JVET-L0128](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4209) CE1-related: Transform tiling for pipelined processing of large CUs [C. Rosewarne, A. Dorrell (Canon)]

Was reviewed in BoG JVET-L0658

[JVET-L0576](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4686) Crosscheck of JVET-L0128 (CE1-related: Transform tiling for pipelined processing of large CUs) [C.-M. Tsai (MediaTek)] [late]

[JVET-L0129](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4210) CE1-related: Chroma block coding and size restriction [C. Rosewarne, A. Dorrell (Canon)]

Prior to VTM-2.0, a single coding tree was used in VVC, resulting in chroma blocks and luma block sizes being related by chroma format. This results in very small chroma blocks (e.g. 2x2, 2x4, and 4x2) and a corresponding very short feedback path for intra reconstruction. Since the adoption of separate trees in intra, it is possible to apply different constraints in the chroma coding tree compared to the luma coding tree. This contribution proposes to restrict split options in the chroma coding tree for intra such that 2x2, 2x4, and 4x2 blocks do not occur. Moreover, since the remaining chroma blocks of width or height of two have minimum opposing dimension of eight, it is proposed to use a 2x8 or 8x2 coefficient group size instead of a 2x2 coefficient group size. In AI config the results are 0.03%, 0.32%, 0.44% in Y, Cb, and Cr channels, respectively. In RA the corresponding results are 0.02%, 0.32%, and 0.37% and in LDB the corresponding results are -0.04%, -0.12%, 0.00%.

Other proposals target this issue: L0137, L0372, L0548

Memory bandwidth is probably the more severe issue with small block sizes, whereas processing a length-2 transform should be trivial.

AHG to assess worst-case memory bandwidth for inter and the pipeline dependency for intra, luma and chroma for different block sizes such as 2x2, 4x2, Nx2, 4x4, considering common memory access models and cache mechanisms (if possible). Also investigate the compression loss that would occur for such cases.

It is reported that the problem is also to be discussed in context of CE4 related contributions. A relevant mandate was added in AHG16 to study.

[JVET-L0674](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4788) Crosscheck of JVET-L0129 (CE1-related: Chroma block coding and size restriction) [B. Wang, A. M. Kotra (Huawei)] [late]

[JVET-L0137](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4218) CE1-related: Minimum block size restriction [J. Choi, J. Heo, S. Yoo, L. Li, J. Choi, J. Lim, S. Kim (LGE)]

In VTM2.0.1, a CU can be split into 4x4 luma block in both intra and inter slices. A size of minimum block (CU or PU) plays an important role for worst case complexity in aspects of memory bandwidth and throughput in hardware architecture. In addition, the coding performance impact of small block coding is getting less significant but requires higher worst case complexity as input video resolution increases. Therefore, this contribution suggests minimum block size restriction methods as follows:

-Method 1: chroma 2x2 block is restricted in I slice, and luma 4x4 and chroma 2x2 are restricted in P and B slice.

-Method 2: luma 4x4 block and chroma 2x2 block are restricted in all slices.

The experimental results for Method 1 reportedly show luma BD-rate losses of 0.00%, 0.22% and 0.18% compared to VTM2.0.1 in AI, RA and LB configurations, respectively. The experimental results for Method 1 reportedly show luma BD-rate losses of 0.46%, 0.36% and 0.29% compared to VTM2.0.1 in AI, RA and LB configurations, respectively. In addition, the BD-rate changes for Method 2 were found to be reduced to 0.19%, 0.17% and 0.12% for UHD and HD test sequences.

An interesting aspect is that the losses are less severe in case of high resolution, where the memory bandwidth is a more severe issue. This would not resolve a case where the same decoder would either decode UHD or four HD streams simultaneously (as the constraint would only apply for UHD). Applying at HD and above might be useful.

It is mentioned that the contribution likely did not consider restricting affine and other subblock related motion comp (as these are implicitly using 4x4) – disabling them would result in higher loss.

A potential solution for limiting memory bandwidth problems with subblock MC tools and 4x4 block size would be an encoder restriction that would not allow large variation. (contribution L0396 is related to this).

[JVET-L0482](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4586) Crosscheck of JVET-L0137 (CE1-related: Minimum block size restriction) [M. G. Sarwer (MediaTek)] [late]

[JVET-L0184](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4275) CE1-related: Flexible Luma and Chroma Block Partitioning Trees Separation [J. An, Y.-C. Sun, J. Lou (Alibaba)]

This contribution proposes a flexible luma and chroma block partitioning trees separation method. The luma and chroma block partitioning trees can be separated under specific block size for both intra and inter slices. Compared to the current structure, the proposed method has the advantages including firstly, the minimum CB size for luma and chroma can be set independently also for inter slice; secondly, the intra and inter slices can share the same block partitioning structure with only high-level parameter adjustable; thirdly, the proposed method is more flexible, the current VTM is a special configuration of the proposed method. For inter slice, a cross component motion information prediction is proposed to reduce the bit cost of the chroma motion information signalling due to the trees separation. Currently, the implementation is finished for intra slice.

No gain and incomplete implementation. No action at this point.

[JVET-L0578](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4688) Crosscheck of JVET-L0184 (CE1-related: Flexible luma and chroma block partitioning trees separation) [C.-M. Tsai (MediaTek)] [late]

[JVET-L0185](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4276) AHG11 & CE1-related: Luma 2xN and Nx2 Block Partitions Support [J. An, Y.-C. Sun, J. Lou (Alibaba)]

This contribution proposes to support luma 2xN and Nx2 block partitions under the current QTBTT block partitioning structure by decreasing the luma minMtSize down to 2 luma samples for I slice. The experiments results show that 4.7% BD-rate gain for class F, and 12% BD-rate gain for SCC class are achieved, under all intra configuration, with 10% encoding time increase and 24% decoding time increase.

some changes are as follows:

* The mode storage unit is modified to 2x2 sample level instead of 4x4 (software change);
* For the transform of 2xN (and Nx2) luma CB, only DCT2 is used, the DST7, and DCT8 are not supported;
* For the deblocking of luma 2-sample edge, the filtering decision and filtering operations are all changed to 2-line processing instead of 4-line processing.

Mostly gain for screen content – gain 0.24% for CTC

Hints were made as follows:

- was it tested together with CPR?

- Restricting minimum block to 16 samples, such as 2x8?

It is generally noted that this might cause memory/pipelining problems

Further study recommended – it needs to be identified in the study of the AHG (see under L0129) what the implementation impact would be.

[JVET-L0629](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4742) Cross-check of contribution JVET-L0185 on Luma 2xN and Nx2 Block Partitions Support [Y. Zhang, H. Huang (Qualcomm)] [late]

[JVET-L0217](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4308) Non-CE1: Relation Between QT/BT/TT Split Constraint Syntax Elements [H. Gao, S. Esenlik, J. Chen, B. Wang, A. M. Kotra (Huawei)]

It is proposed to signal the QT, BT and TT split size and depth limitations differentially in order to guarantee complete partitioning of the picture frame. It is asserted that the ambiguities in the VVC draft are resolved with the proposed changes.

There could be ambiguities in the current signalling of constraints. Proponents were asked to clarify with B. Bross if this is a viable solution and report back. It was confirmed that Problems 1 and 3 are appropriate solutions. Another straightforward change relates to the syntax element BT\_size. Confirmed text is in v4.

Decision (ed./text improvement): Adopt JVET-L0217 (as per v4)

[JVET-L0540](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4648) Cross-check of L0217: Non-CE1: Relation Between QT/BT/TT Split Constraint Syntax Elements [J. Ma (HHI)] [late]

[JVET-L0218](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4309) Non-CE1: Overriding QT/BT/TT Split Constraint Syntax Elements [H. Gao, S. Esenlik, J. Chen, B. Wang, A. M. Kotra (Huawei)]

A mechanism is proposed to enable overriding of the split constraint syntax elements in the slice header. According to the proposal syntax elements that are used in the derivation of minimum quadtree split size, maximum binary tree split size and maximum multi-type tree split depth are signalled in the SPS and can be overridden in the slice header. It is asserted that the proposed mechanism provides more flexibility for encoders to adapt to the scene characteristics and to encoding time limitations.

Powerpoint deck to be uploaded.

It is supported by several experts that more flexibility is desirable in using/signalling the max block size and depth of tree elements. Several solutions are suggested here, including BT, TT and separate signalling for chroma. The basic parameters are signalled at SPS separately for intra and inter, with possibility to override them specifically in a given slice.

Proponents should discuss this further with proponents of JVET-L0051 (and E. Mora who also expressed interest) and suggest a unified solution. An alternative solution of using PPS signalling instead of slice header should also be considered (which would e.g. allow to use this commonly for key frames, temporal levels, etc.). See new contribution JVET-L0678.

[JVET-L0541](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4649) Cross-check of L0218: Non-CE1: Overriding QT/BT/TT Split Constraint Syntax Elements [J. Ma (HHI)] [late]

[JVET-L0313](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4408) CE1-related: Non-square virtual pipeline data unit [M. Xu, X. Li, S. Liu (Tencent)]

Was reviewed in BoG JVET-L0658

[JVET-L0509](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4615) Cross-check of JVET-L0313: CE1-related: Non-square virtual pipeline data unit [J. Ma (HHI)] [late]

[JVET-L0361](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4458) CE1-related: Context modeling of CU split modes [Y. Zhao, H. Yang, J. Chen (Huawei)] [late]

This contribution proposes a modified context modeling for CU partitioning flag signalling. The proposed method achieves −0.06%, −0.12%, and −0.20% luma BD-rates for the AI, RA, and LB settings of CTC, respectively.

Two versions:

- increasing number of context models from 17 to 19 gives 0.0%, 0.10%, 0.16% luma BR red. for AI/RA/LD

- increasing number further to 22 gives 0.06%/0.12%/0.20% luma BR red. for AI/RA/LD

Some experts expressed this is not adding significant complexity (no new context coded bins, only more complex models which need some additional storage).

Concern was expressed by proponents of JVET-K0362 (part of which is included here), and by cross-checker. It was for example mentioned that the proposal requires additional checks depending on block size threshold to determine which context model would be applied. These concerns were later resolved, abd therefore consensus was reached to adopt the proposal (follow-up in track A Tue afternoon)

Decision: Adopt JVET-L0361 (version with 22 context models)

[JVET-L0487](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4592) Cross check of CE1-related: Context modeling of CU split modes (JVET-L0361) [M. W. Park (Samsung)] [late]

[JVET-L0372](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4469) CE1-related: Constrained chroma block partitioning [Y. Zhao, H. Yang, J. Chen (Huawei)] [late]

This contribution constrains the split of chroma blocks in I slice to avoid 2xN or Nx2 chroma blocks. For dual-tree setting, the minimum QT/BT/TT size of chroma tree is configured as 8 or limiting the chroma tree splits that result in 2xN or Nx2 chroma blocks. For single tree setting, when a split mode generates 2xN or Nx2 chroma blocks in child nodes, the luma block of the node splits using this split mode while the chroma blocks do not further split. In one test, N is from 2 to CTUSize/2, i.e., removing all chroma blocks with one side equal to 2, and the proposed method reportedly leads to 0.15%/1.21%/1.45% and 0.22%/-0.21%/-0.11% Y/U/V BD-rates loss for separate trees and single tree in AI settings, respectively. In another test, N is from 2 to 4, i.e., remove chroma blocks of 2x2, 2x4 and 4x2 which contain fewer than 16 chroma samples, the proposed method leads to 0.03%/0.30%/0.41% and 0.08%/-0.35%/-0.18% Y/U/V BD-rates loss for separate trees and single tree in AI settings, respectively.

[JVET-L0539](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4647) Cross-check of L0372: CE1-related: Constrained chroma block partitioning [J. Ma (HHI)] [late]

[JVET-L0548](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4657) CE1-related: On maximum/minimum allowed QT/BT/TT sizes for chroma [C.-M. Tsai, C.-W. Hsu, C.-Y. Chen, T.-D. Chuang, Y.-W. Huang, S.-M. Lei (MediaTek)] [late]

When separate coding tree between luma and chroma is enabled in intra slices, maximum/minimum allowed QT/BT/TT sizes for chroma can be different from those derived from corresponding maximum/minimum QT/BT/TT sizes for luma according to chroma subsampling format. In this contribution, related parameters are named as MaxQtSizeC, MaxBtSizeC, MaxTtSizeC, MinQtSizeC, MinBtSizeC, and MinTtSizeC, where C stands for chroma. Results of four tests compared with VTM2.0.1 are reported as follows.

VTM2.0.1: {MaxQtSizeC, MaxBtSizeC, MaxTtSizeC, MinQtSizeC, MinBtSizeC, MinTtSizeC} in units of chroma samples = {32, 32, 16, 2, 2, 2}

Test1: Related parameters = {32, 32, 32, 2, 2, 2}  
AI BD-rates = -0.08% (Y), -0.91% (U), -0.94% (V); EncT=103%; DecT=101%  
RA BD-rates = 0.00% (Y), -0.32% (U), -0.31% (V); EncT=100%; DecT=100%  
LB BD-rates = 0.01% (Y), -0.09% (U), -0.44% (V); EncT=100%; DecT=99%

Test2: Related parameters = {32, 32, 16, 4, 2, 2}  
AI BD-rates = 0.00% (Y), 0.04% (U), 0.04% (V); EncT=100%; DecT=100%  
RA BD-rates = 0.00% (Y), -0.01% (U), 0.00% (V); EncT=100%; DecT=100%  
LB BD-rates = 0.00% (Y), 0.04% (U), -0.09% (V); EncT=100%; DecT=99%

Test3: Related parameters = {32, 32, 32, 4, 2, 2}  
AI BD-rates = -0.08% (Y), -0.89% (U), -0.91% (V); EncT=103%; DecT=100%  
RA BD-rates = -0.01% (Y), -0.36% (U), -0.30% (V); EncT=100%; DecT=100%  
LB BD-rates = -0.02% (Y), -0.23% (U), -0.50% (V); EncT=100%; DecT=101%

Test4: Related parameters = {32, 32, 32, 4, 4, 4}  
AI BD-rates = 0.06% (Y), 0.30% (U), 0.51% (V); EncT=100%; DecT=99%  
RA BD-rates = 0.03% (Y), 0.55% (U), 0.78% (V); EncT=100%; DecT=100%  
LB BD-rates = -0.05% (Y), 0.08% (U), 0.06% (V); EncT=100%; DecT=97%

It is suggested to Test1 or Test4 for consistent settings between QT, BT, and TT. It is also suggested that Test1 is slightly preferred than Test4 because of coding efficiency.

Related to restricting minimum block sizes. Test 2..4 disallow 2-pixel sizes for chroma

[JVET-L0668](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4782) Crosscheck of JVET-L0548 (CE1-related: On maximum/minimum allowed QT/BT/TT sizes for chroma) [C. Rosewarne (Canon)] [late]

[JVET-L0551](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4660) CE1-related: fix on ternary split restriction [Y. Zhao, J. Chen (Huawei)] [late]

Was reviewed in BoG JVET-L0658

[JVET-L0678](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4792) QT/BT/TT Split Constraint Syntax Elements Signalling Method [H. Gao, S. Esenlik, J. Chen, B. Wang, A. M. Kotra (Huawei), M. Park, M. W. Park, K. Choi (Samsung)] [late]

Text-wise, this was considered OK, confirmed by B. Bross. The split constraints in the CTC were agreed not to be changed, but the encoder needs to be modified to signal them.

Decision: Adopt JVET-L0678.

## CE2 related – Adaptive loop filter (4)

Contributions in this category were discussed Saturday 6 Oct 1845–2000 (chaired by GJS).

[JVET-L0083](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4164) CE2-related: Reduction of bits for ALF coefficient fractional part [Y.-C. Su, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

In the contribution, it is proposed to reduce bits for adaptive loop filter (ALF) coefficient fractional part. In VTM2.0.1, the fractional part of each ALF coefficient is represented in nine bits. It is reported that, compared with VTM2.0.1, 6-bit fractional part results in 0.10%, 0.09%, and -0.04% luma BD-rates for AI, RA, and LB, respectively, and 7-bit fractional part results in -0.01%, -0.03%, and -0.09% luma BD-rates for AI, RA, and LB, respectively. The reduction of bits for ALF coefficient fractional part is also tested on top of CE2.2.2 from JVET-L0082. The real value range of the center ALF coefficient is within [0.0, 2.0), the real value range of non-center ALF coefficients is within [-1.0, 1.0), and the number of bits for ALF coefficient fractional part is six or seven. It is shown that compared to VTM2.0.1, 6-bit fractional part with the reduced ranges results in 0.10%, 0.08%, and -0.03% luma BD-rates for AI, RA, and LB, respectively, and 7-bit fractional part with the reduced ranges results in -0.01%, -0.04%, and -0.11% luma BD-rates for AI, RA, and LB, respectively. With the 7-bit fractional part with the reduced ranges for ALF coefficients, the numbers of required bits to represent a non-center coefficient and a center coefficient are reduced from 11 to 8 and 15 to 8, respectively, when compared to VTM2.0.1. There are almost no run time changes in all the above tests.

This doesn’t change how the data is coded – only reduces the number of fractional bits for ALF coefficients from 9 to 7. This would enable use of an 8-b multiplier instead of a higher-precision multiplier. This a refinement relative to the CE2.2.2.

It was not clear how this could produce gain.

Decision: Adopt (text is in the contribution).

[JVET-L0464](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4568) Crosscheck of JVET-L0083 on CE2-related: Reduction of bits for ALF coefficient fractional part [G. Clare, F. Henry (Orange)] [late]

[JVET-L0392](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4489) CE2-related: Test results for corrected initial context states for ALF [N. Hu, V. Seregin, M. Karczewicz (Qualcomm)]

In VTM-2, for each coding tree block, a flag is signalled with a context to indicate whether ALF is applied. This contribution asserts that there was an error in the values of the initial context states for CTB flags, that the association of the values to the slice types was incorrect. It is proposed to use the initial context states as were originally defined in JVET-K0564, which swaps the values associated with slice types in the current VTM.

The change generally makes very little difference, but some gain was shown (esp. for chroma) in a few test cases.

Decision (minor BF): Adopted.

[JVET-L0409](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4507) Non-CE2: Filter Coefficients simplification for filtering complexity reduction in ALF [S. Sethuraman (Ittiam)] [late]

In this proposal, a method is proposed for normatively constraining the maximum number of ones in the binary representation of the absolute value of all the filter coefficients except the central coefficient in ALF with the aim of simplifying the complexity associated with the multiplications required for the non-separable 2-D filtering. Specifically, the number is constrained to a low value such as 2 or 3 so that the multiplication can be realized with just 2 or 3 shifts and 1 or 2 additions, respectively. The proposal also presents results related to an earlier proposal that constrained the absolute value of certain filter coefficients to be a power of 2. The results reportedly indicate that the approximation results in 0.14% penalty in luma coding efficiency for the 3-shift option and slightly higher drop for the 2-shift option.

The ALF method adopted in VTM-2.0 has 13 multiplies per output sample.

The results had not yet been measured on VTM 2.0; they were based on VTM 1.

It was commented that the constraint requirements complicate the encoder’s filter optimization.

A different method had been tested in CE2.5.1, but it had been concluded that such a scheme was unlikely to provide a substantial benefit for implementations. This proposed scheme has somewhat more loss than that one and is not fundamentally different in spirit. It was commented that the more critical issue is line buffer reduction (for both deblocking and ALF). No action or CE was planned.

[JVET-L0664](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4778) CE2-related: Test results of disabling 5x5 ALF for luma component [N. Hu, V. Seregin, M. Karczewicz (Qualcomm)] [late]

In VTM-2, adaptive loop filter can be applied using 5x5 or 7x7 filter shapes to luma component. The filter shape is controlled by signalling a flag alf\_luma\_type\_flag at slice header. This contribution presents the results of disabling 5x5 filter for luma component, i.e. only 7x7 filters can be applied. Test results reportedly show 0.00%, 0.02%, 0.06% BD-rate loss for luma component for AI, RA and LDB configurations respectively.

It was noted that to the degree that there is any loss at all from this, it may be due to testing only one filter value instead of testing more than one. The loss was considered negligible.

Decision: Remove the alf\_luma\_type\_flag and the conditioning on it that results in signalling of 5x5 as a special case for luma.

## CE3 related – Intra prediction and mode coding (45)

Contributions in this category were discussed Sunday 7 Oct 1400–1800 and Monday Oct 8 1415-1545 (chaired by JRO).

[JVET-L0053](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4134) CE3-related: Chroma DM modification [N. Choi, M. W. Park, K. Choi (Samsung)]

Chroma DM is a mode to directly use the intra prediction mode of the corresponding luma block. If the separate tree for luma and chroma is used, there might be multiple luma blocks corresponding to the current chroma block. In this case, the intra prediction mode of the corresponding luma block covering the top-left pixel position of the current chroma block is directly inherited. It is important to choose an appropriate luma block among them to improve coding efficiency. Therefore, this contribution proposes to change the position from top-left to the center for finding a corresponding luma block. The simulation results reportedly show –0.10% BD-rate on AI for both VTM and BMS. In addition to this, this contribution proposes to use a single DM for MDMS instead of multiple DMs. The simulation results reportedly show –0.17% BD-rate on AI for both VTM and BMS.

The first change is also proposed similarly in JVET-L0272. The gains reported are similar but slightly different (e.g. small chroma gain is reported in L0272), which is asserted to be due to the usage of a different software (BMS vs. VTM).

Decision: Adopt JVET-L0053 first aspect / JVET-L0272. Proponents shall check if their text is identical and if not, unify them.

Other “simplified” MDMS are proposed in JVET-L0139, JVET-L0630 – investigate this aspect in next CE

[JVET-L0498](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4604) Crosscheck for L0053 (CE3-related: Chroma DM modification) [L. Li (LGE)] [late]

[JVET-L0065](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4146) CE3-related: One-line CCLM for reduction of reference sample lines [J. Lee, J. Byeon, S. Park, D. Sim (KWU)]

This contribution presents a modified Cross Component Linear Model (CCLM) methods with one-line luminance sample line for down-sampling process. In the CCLM mode in VTM2.0.1, two upper neighbouring reconstructed luminance lines are required in the down-sampling process. The proposed method uses one reconstructed luminance sample line, that is upper adjacent to the corresponding Luma block to the current chroma CU in order to reduce a luminance line buffer. Experimental results show that the proposed method yields BD-rate loss of 0.02%, 0.23%, and 0.22% for three colour components on average over VTM2.0.1 with CCLM, respectively.

The contribution does not need more consideration due to the decision to restrict CCLM only at the CTU boundary (where the advantage would be minor).

JVET-L0329 proposes a similar approach.

[JVET-L0066](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4147) CE3-related: One-line MMLM for reduction of reference sample lines [J. Lee, J. Byeon, S. Park, D. Sim (KWU)] [late]

This contribution proposes a modified Multi Model Linear Model (MMLM) which uses one-line buffer for luminance in down-sampling process. The MMLM mode in BMS-2.0.1 with a macro as ‘--LMChroma=2’ is required four neighbouring reconstructed luminance sample lines in the down-sampling process. The proposed method uses one reconstructed luminance samples line for above side in order to reduce line buffer. Experimental results show an average BD-rate gain 0.27%, 2.38% and 2.23% for three components on average over BMS-2.0.1 with vtm\_config and ‘--LMChroma=2’, respectively.

Same concept as JVET-L0065. The comparison is made for MMLM with 4 lines for computing, therefore the loss is higher. As MMLM is not adopted, no action necessary.

[JVET-L0087](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4168) CE3-related: Boundary PDPC [M. G. Sarwer, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

In this contribution, position dependent intra prediction combination (PDPC) is applied only to top-left boundary samples. Compared to VTM2.0.1, it is reported that the proposed boundary PDPC can simplify the PDPC operation with 0.03% (Y), 0.05% (U), and 0.06% (V) BD-rates for AI.

It is reported that the approach would save a large amount of operations. As the weight of PDPC goes to zero quickly at positions that are farther away from the boundary, optimized hardware or software would not multiplications by 0 anyway.

No further action.

[JVET-L0499](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4605) Crosscheck for JVET-L0087 (CE3-related: Boundary PDPC) [L. Li (LGE)] [late]

[JVET-L0107](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4188) Non-CE3: CCLM performance of extended neighbouring region [S. Wan (NPU), J.-Y. Huo, X.-Y. Chai, Y.-Z. Ma (Xidian Univ.), Y.-F. Yu, Y. Liu (OPPO)]

In this contribution, the coding performance of CCLM is reported through adding the top-right and bottom-left neighbouring samples into the derivation process of the linear model parameters. The simulation results reportedly show that -0.04%, -0.31% and -0.33% BD rate savings on Y, Cb and Cr components respectively for All Intra configuration.

The number N of reference samples is doubled. The complexity of LM derivation would also be doubled, which is undesirable, compared to the small gain.

[JVET-L0108](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4189) Non-CE3: Enhanced-CCLM based on current reconstructed luma (E-CCLM) [J.-Y. Huo, X.-W. Li, J.-L. Wang, Y.-Z. Ma, F.-Z. Yang (Xidian Univ.), S. Wan (NPU), Y.-F. Yu, Y. Liu (OPPO)]

This contribution presents a Cross-Component Linear Model method based on Current reconstructed luma (CCCLM). The linear model parameters and in CCCLM are derived according to the reconstructed luma of current block and reconstructed luma/chroma of neighbouring region. The reported BD-rates over VTM-2.0.1 are −0.14% (Y), −0.57% (U), −0.63% (V) with runtimes 116% (Dec) for AI configuration.



This contribution further introduces a restriction which uses CCCLM only for blocks with the size no larger than 64 samples. The reported BD-rates over VTM-2.0.1 are −0.13% (Y), −0.55% (U), −0.65% (V) with runtimes 102% (Dec) for AI configuration.

The approach requires matching operations at pixel which are difficult to implement. It appears too complex to justify the gain.

[JVET-L0109](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4190) Non-CE3: (LM only) + (E-CCLM) coding performance [J.-Y. Huo, J.-L. Wang, X.-Y. Chai, F.-Z. Yang (Xidian Univ.), S. Wan (NPU), Y.-F. Yu, Y. Liu (OPPO)]

This contribution presents the coding performance by adding CCCLM (proposed in JVET-L108) as an additional LM mode. CCLM and CCCLM are two LM methods which are decided through RD optimization process. The simulation results reportedly show that -0.13%, -2.27% and -2.52% BD rate savings on Y, Cb and Cr components for All Intra configuration.

Combination of L0107 and L0108. See comments there.

[JVET-L0138](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4219) CE3-related: Reduced number of reference samples for CCLM parameter calculation [J. Choi, J. Heo, S. Yoo, L. Li, J. Choi, J. Lim, S. Kim (LGE)]

The CCLM (cross-component linear model) method in the current VTM2 requires complex process to derive the linear model parameter and based on the least mean square algorithm. Considering that the derivation process of the linear model parameters is also required in decoder side, it is necessary to reduce the required complexity. In this proposal, the maximum number of reference sample pairs, which are used in the CCLM parameter determination is restricted to predefined number so that complexity reduction factors relative to worst and average cases become 2 and 8, respectively. The modified subsampling position is also introduced in this proposal, and it can improve the proposed reference sample limitation method.

Experimental results show 0.05%, 0.14%, and 0.10% BD-rate losses on Y, Cb, and Cr components respectively, compared to VTM2.0.1 in All Intra configuration, and the experimental results with the modified subsampling position show 0.01%, -0.05%, and -0.16% BD-rate losses on Y, Cb, and Cr components respectively, compared to VTM2.0.1 in All Intra configuration.

As a new lower method for LM computation was adopted, the number of reference samples is not so critical anymore. Nevertheless, 2x2 chroma is still the worst case, but reducing the number of ref samples from 4 to 2 may not be very effective with the new algorithm. Contributors are encouraged to study if the approach of reducing number of reference samples is still useful with the new LM method.

[JVET-L0568](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4678) Crosscheck of JVET-L0138 (CE3-related: Reduced number of reference samples for CCLM parameter calculation) [Y. Ahn, D. Sim (Digital Insights)] [late] [miss]

[JVET-L0139](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4220) CE3-related: Simplified MDMS [J. Choi, J. Heo, S. Yoo, L. Li, J. Choi, J. Lim (LGE)]

This contribution proposes a simplified MDMS. In this method, chroma intra candidate modes are derived from the simplified DM point searching and the reduced number of context models is used in the binarization of chroma intra modes, compared to the JEM MDMS.

Experimental results with 5 chroma modes show -0.09%, -0.97%, and -1.00% BD rate on Y, Cb, and Cr components, respectively, compared to VTM2.0.1 in All Intra configuration, and 0.00%, -0.83%, and –1.00% BD rate, compared to VTM2.0.1 in Random Access configuration.

Experimental results with 3 chroma modes show x%, x%, and x% bit rate savings on Y, Cb, and Cr components, respectively, compared to VTM2.0.1 in All Intra configuration, and x%, x%, and x% bit rate savings, compared to VTM2.0.1 in Random Access configuration.

Complexity-wise much less than MDMS in BTM, but the luma gain over VTM drops from 0.2% to 0.1%, whereas the chroma gain stays similar (around 1%). Complexity in operation count not much higher than VTM. See subsequent table.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Max number of Luma DM point to access** | **Max number of neighbours to access** | **Max layers of if conditions** | **Max number of comparison operator** | **Max number of logical operators** | **Max number of assignment operators** |
| **VTM2** |  | 1 | 0 | 1 | 4 | 0 | 9 |
| **MD MS** |  | 5 | 5 | 4 | 39 | 28 | 80 |
| **JVET-L0139** | **5 mode** | 2 | 0 | 3 | 5 | 1 | 18 |
| **JVET-L0139** | **3 mode** | 2 | 0 | 2 | 3 | 1 | 13 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Max number of increments** | **Max number of bit operation** | **Number of Context modeling for MPM coding** | **number of full RDO checks** | **Has LUT?** | **LUT size** |
| **VTM2** |  | 0 | 0 | 2 | 6 | N | 0 |
| **MD MS** |  | 5 | 2 | 6 | 6 | Y | 68 |
| **JVET-L0139** | **5 mode** | 2 | 2 | 2 | 6 | N | 0 |
| **JVET-L0139** | **3 mode** | 2 | 2 | 2 | 4 | N | 0 |

Further study in CE

[JVET-L0594](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4707) Crosscheck of JVET-L0139 (CE3-related: Simplified MDMS) [Y. Kidani, K. Kawamura, S. Naito (KDDI)] [late]

[JVET-L0152](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4233) CE3-related: Simplification of PDPC [J. Lee, H. Lee, S.-C. Lim, J. Kang, H. Y. Kim (ETRI)]

This contribution presents modification of position dependent intra prediction combination (PDPC). It includes three modifications which are block size restriction, removal of interpolation, and restriction on wide angle intra prediction modes. It is reported that the average luma BD-rate gain of all the modifications for AI case is -0.03% compared to VTM 2.0.1.

- PDPC not used for64x64

- PDPC applied to less prediction samples by modyfying the weight

- no bilinear interpolation in PDPC

- no PDPC for wide angle modes

The first two aspects give marginal gain

The third aspect would be a straightforward complexity reduction with marginal loss. It is however asked why PDPC is not using the nearest neighbour

The fourth aspect is not a complexity reduction, as PDPC needs to be implemented anyway for other modes.

Further study on the third aspect.

[JVET-L0620](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4733) Cross-check of JVET-L0152 (CE3-related: Simplification of PDPC) [G. Laroche (Canon)] [late]

[JVET-L0154](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4235) CE3-related: MPM Modifications for Intra Mode Coding [Y. -U. Yoon, D. -H. Park, J. -G. Kim (KAU), J. Lee, J. Kang (ETRI)]

This contribution proposes two modifications of most probable mode (MPM) for intra mode coding. The first is modification of positions deriving MPM candidates and the second is modification of context models for MPM index. First, in the current VTM software, the 3 MPM candidates are derived from neighbours which are adjacent to above-left corner of the current block. In this contribution, the positions deriving MPM candidates are modified to be the same as the positions deriving MERGE candidates. Second, 3 MPMs are signalled by MPM\_FLAG and MPM\_IDX. The first bin of MPM\_IDX is using the bypass coding. In this contribution, the first bin of MPM\_IDX is coded by two context models according to predefined condition. This contribution reports the performances on the four tests below:

* Test 1: modified positions deriving MPM candidates
* Test 2: modified context model of MPM\_IDX with two context models
* Test 3: modified context model of MPM\_IDX with a context model and bypass
* Test 4: Test 2 with Test 1

Under VTM configuration, the experiment results reportedly show 0.07%, 0.08%, 0.10% and 0.15% bitrate savings without increase of the encoding/decoding running time for Test 1, Test 2, Test 3, and Test 4, respectively.

Test 2 and Test 3 have parsing dependency (making coding dependent on neighbour mode conditions)

Test 1 could be a simple and straightforward modification without additional complexity, gives small gain. The same is used in 6 MPM case.

Result for RA not included. Further study recommended if VTM would continue using 3 MPM.

[JVET-L0457](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4559) Crosscheck of JVET-L0154 on CE3-related: MPM Modifications for Intra Mode Coding [T. Ikai (Sharp)] [late]

[JVET-L0155](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4236) CE3-related: Most Frequent Mode (MFM) for Intra Mode Coding [Y. -U. Yoon, D. -H. Park, J. -G. Kim (KAU), J. Lee, J. Kang (ETRI)]

At the last meeting, 3 MPMs and 67 modes are adopted in VTM 2.0.1 software. As the number of intra modes are increased, more efficient coding of intra mode is require. This contribution proposes the most frequent mode (MFM) for intra mode coding. The MFM means the most frequent mode to be derived from neighbours and is indicated by MFM\_FLAG. The decoder parses MFM\_FLAG and derives one mode from neighbours if MFM\_FLAG is true, otherwise, parses MPM\_FLAG. This contribution reports the performances on three test including the MFM in the RD-check list and adjusting the number of RD-checks for the MPM. Based on the same number of RD-checks as the current VTM-2.0.1 software, the proposed method reportedly shows 0.28% bitrate saving without increase of encoding/decoding running time.

No RA results yet

This is kind of “4 MPM”=”MFM+3MPM”. It has more context coded bins than the currently investigated 6 MPM proposals, and also higher complexity in deriving the MFM+MPMs. Performance when coding runtime is not increased is similar to 6 MPM proposals as well (around 0.3%).

No action at this point.[JVET-L0458](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4560) Crosscheck of JVET-L0155 on CE3-related: Most Frequent Mode (MFM) for Intra Mode Coding [T. Ikai (Sharp)] [late]

[JVET-L0164](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4255) CE3-related: Decoder-side Intra Mode Derivation [E. Mora, A. Nasrallah, M. Raulet (ATEME)]

This contribution proposes a new intra coding mode that is named, in the rest of this document, DIMD (**Decoder-side Intra Mode Derivation**). In DIMD mode, the intra prediction mode is no longer searched for at the encoder but rather derived using previously encoded neighbouring pixels through a gradient analysis. DIMD is signaled for intra coded blocks using a simple flag. At the decoder, if the DIMD flag is true, the intra prediction mode is derived in the reconstruction process using the same previously encoded neighbouring pixels. If not, the intra prediction mode is parsed from the bitstream as in classical intra coding mode. DIMD brings 0.3% gain on average (and up to 0.7% on some sequences) over VTM-2.0.1 in an All Intra configuration, with limited additional decoding complexity (2%).

Histogram of oriented gradient is computed from an L-shaped neighbourhood.

Additional results indicate that runtime can be further reduced by restricting to small block sizes (particular RD checks)

Though the method does not have a parsing dependency issue, it likely has a latency issue, provided that the immediately preceding decoded block (which needs to be reconstructed) would be included in HoG analysis. It is pointed out that determining the orientation in transform domain could also solve this issue.

Study in CE, including the latency and other implementation aspects.

[JVET-L0675](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4789) Crosscheck of JVET-L0164 (CE3-related: Decoder-side Intra Mode Derivation) [J.-M. Thiesse, D. Nicholson, D. Gommelet (VITEC)] [late]

[JVET-L0204](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4295) CE3-related: Disabling PDPC based on availability of reference samples [V. Drugeon (Panasonic)]

This contribution proposes to disable PDPC for certain intra blocks based on the availability of reference samples around the block. The results show tiny gains in both complexity and coding efficiency. Although the benefit is very small, the author believes that this is a logical modification of the PDPC process that could be especially beneficial for low resolution sequences and test conditions that differ from the CTC.

In VTM, non-available reference samples are padded by the last available sample.

The idea of disabling PDPC at block level seems straightforward, simple and logical, but results are still incomplete and no cross-check is available. Further study, more results expected for next meeting.

[JVET-L0239](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4330) CE3-related: Enabling different chroma sample location types in CCLM [P. Hanhart, Y. He, Y. Ye (InterDigital)]

In VTM-2.0, the cross-component linear model (CCLM) tool assumes chroma sample location type 0 when downsampling the reconstructed chroma samples. However, other chroma sample location types should be supported. For example, in ITU-R BT.2020, it is a requirement that the chroma sample location type 2 is used. This contribution investigates the impact of the CCLM default downsampling filter on coding efficiency when encoding an input video with a chroma sample location type that is different from type 0. Simulation results for 360° content generated using chroma sample location types 1, 2, and 3 show an average coding loss in the range of 1% to 2% on the chroma components when compared to when the 360° content is generated using chroma sample location type 0. To compensate for this coding loss, this contribution proposes to use different downsampling filters in CCLM mode based on the chroma sample location type of the input video. In this way, the coding loss can be completely avoided. Simulation results for HDR/WCG content encoded using chroma sample location type 2 CCLM downsampling filter show an average coding gain in the range of -4.5% to -6.9% for the colour components based on the wPSNR metric.

Used for determining the model and for prediction itself.

Interesting problem pointed out. Further study recommended. E.g.

- might be more generic to signal hor/ver offsets rather than types?

- which interpolation filters for LM determination and for prediction?

It is also noted that the number of lines for CCLM should not be increased.

Study in CE – use HDR content.

[JVET-L0665](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4779) Crosscheck of JVET-L0239 (CE3-related: Enabling different chroma sample location types in CCLM) for HDR-PQ content [T. Lu (Dolby)] [late]

[JVET-L0676](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4790) Cross-check of JVET-L0239 (CE3-related: Enabling different chroma sample location types in CCLM) [A. K. Ramasubramonian, G. Van der Auwera (Qualcomm)] [late]

[JVET-L0272](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4368) CE3-related: Modified chroma derived mode [L. Zhang, K. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

In VTM2.0, separate block partitioning structure for luma and chroma components is enabled in I slices. Therefore, one chroma coding block may correspond to multiple luma coding blocks. When deriving the chroma derived mode (DM), the intra prediction mode of the luma coding block containing the top-left luma sample in the corresponding luma block is utilized. It is proposed to use the intra prediction mode of the luma coding block covering the center position of the corresponding luma block as chroma DM. Simulation results reportedly show that the proposed method achieves 0.11% BD rate reduction under All Intra Main10 configuration.

Adopted (see notes under JVET-L0053)

[JVET-L0557](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4667) Crosscheck of JVET-L0272 (CE3-related: Modified chroma derived mode) [N. Choi (Samsung)] [late]

[JVET-L0279](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4374) CE3-related: Unification of angular intra prediction for square and non-square blocks [L. Zhao, X. Zhao, S. Liu, X. Li (Tencent)]

In this contribution, two modifications are proposed to unify the angular intra prediction for square and non-square blocks. Firstly, angular prediction directions are slightly modified to cover diagonal directions of all block shapes. Secondly, it is proposed to keep all angular directions within the range between bottom-left diagonal direction and top-right diagonal direction for all block sizes. Simulation results reportedly show that, with almost no impact on the encoder or decoder run-time, average -0.06% BD-rate gain is achieved on top of VTM2.0.1 under all intra (AI) configuration.

Several experts who are familiar with wide-angle modes (including companies who originally proposed it) expressed that this is a beneficial simplification and clean design.

It is also confirmed that there is no change to the reference lines that are used, and that it is also compatible with multi-line intra prediction that was adopted in CE3.

Decision: Adopt JVET-L0279

[JVET-L0534](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4642) Crosscheck of L0279: CE3-related: Unification of angular intra prediction for square and non-square blocks [Y.-W. Chen, X. Wang (Kwai Inc.)] [late]

[JVET-L0280](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4375) CE3-related: Intra mode coding [L. Zhao, X. Zhao, X. Li, S. Liu (Tencent)]

In this contribution, it is proposed to signal 6 MPMs and only 32 remaining modes for each coding unit. To code an intra prediction mode, an MPM flag is firstly signaled. If the MPM flag is true, then truncated unary codeword with bypass coding is used to signal the MPM index. Otherwise, 5-bit fixed length coding is used to signal the remaining mode. Simulation results reportedly show that, with almost no impact on run-time, average -0.49% and -0.16% BD-rate change is achieved on top of VTM2.0.1 for all intra (AI) and random access (RA) configuration under common test condition.

The 32 remaining modes are determined from the MPMs.

The MPM derivation is same as in JEM

More analysis required to assess the complexity of the selection process of 32 remaining modes

It was also asked if this causes visual artifacts

The gain compared to 6 MPM with full set of modes is probably lower.

Further study in CE (with the adopted version of 6 MPM)

[JVET-L0549](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4658) Crosscheck of JVET-L0280 (CE3-related: Intra mode coding) [M. G. Sarwer (MediaTek)] [late]

[JVET-L0291](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4386) CE3 Related: Extended reference sample construction for longer interpolation filter in intra prediction [S.Yoo, J. Heo, J. Choi, L. Li, J. Choi, J. Lim (LGE)]

In HEVC (and JEM), only a bi-linear interpolation filter was used for prediction of sub-pel position. However, in CE3-Intra prediction and mode coding, longer interpolation filters (i.e., 4-tap and 6-tap filters) are being considered. In the conventional way of reference sample construction, it is not available for the very-end predicted samples (some right bottom samples in a currently predicted block) to refer to the reconstructed samples in the neighbour blocks. In this contribution, an extension of a reference sample construction is proposed for longer interpolation filter. Specifically, the number of the reference samples is extended from the neighbour blocks. The experimental results are reportedly shown that 0.04% and 0.01% BD-rate coding gains from VTM-AI and VTM-RA respectively.

In RA configuration, loss (+0.17/+0.22%) is observed in chroma compared to 4-tap standalone.

No obvious benefit compared to 4-tap.

[JVET-L0627](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4740) Cross-check of JVET-L0291 "CE3-Related: Extended reference sample construction for longer interpolation filter in intra prediction" [V. Rufitskiy, A. Filippov, J. Chen (Huawei)] [late]

[JVET-L0329](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4425) CE3-related: CCLM prediction with single-line neighbouring luma samples [K. Zhang, L. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

In VTM-2.0, CCLM prediction mode employs a six-tap down-sampling filter to down-sample neighbouring luma samples during CCLM parameter derivation process. As a result, two rows of neighbouring luma samples above the current block and three columns of neighbouring luma samples left to the current block are required, which increases the line buffer size and computational complexity. In this contribution, down-sampling filters with less taps are applied on the neighbouring luma samples. Meanwhile, only neighbouring luma samples located at one row above and one column left to the current block are required. Simulation results reportedly show 0.08% and 0.03% BD-rate loss under All Intra (AI) and Random Access (RA) configurations, respectively with almost the same running time.

The r1 document also contains additional results which use the VTM (6-tap) filter at the left boundary and the 1D (3-tap) filter at the top boundary, which has no loss (-0.01% luma in RA/AI).

It is however not known how this would interact with MDLM which was adopted to VTM. Investigate in CE, as it might be seen as a complexity reduction which would be reasonable if it comes with no loss.

It is noted that the number of operations for the filters is less important than the reduction of the line buffer at CTU boundary, which was already resolved from the CE3 adoption.

[JVET-L0606](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4719) Cross-check of JVET-L0329 (CE3-related: CCLM prediction with single-line neighbouring luma samples) [A. K. Ramasubramonian, G. Van der Auwera (Qualcomm)] [late]

[JVET-L0341](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4438) CE3-related: CCLM coefficients derivation method without down-sampling operation [X. Ma, H. Yang, J. Chen (Huawei)]

In this contribution, a CCLM coefficients derivation method without down-sampling operation is proposed. In which, the maximum/minimum luma template sample values are obtained by checking the neighbouring samples of current luma block, directly. Also, corresponding chroma template sample values are obtained based on the position of the selected luma template samples. Only 1 row and 1 column neighbouring samples of current luma block will be checked. Simulation results reportedly show BD rate on Y, Cb and Cr components for AI configuration over VTM2.0.1 is 0.26%, 1.81%, and 1.18%, with 100% EncT, 100% DecT;

The method is built on top of L0191 (simplified CCLM computation). Relative to that, it has loss in performance (loss in luma and chroma), since the samples are downsampled without filtering.

The filtering is complexity-wise not a big issue to justify the loss.

[JVET-L0604](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4717) Crosscheck of JVET-L0341: CE3-related: CCLM coefficients derivation method without down-sampling operation [P.-H. Lin, C.-C. Lin (ITRI)] [late]

[JVET-L0342](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4439) CE3-related: Classification-based mean value for CCLM coefficients derivation [X. Ma, F. Mu, H. Yang, J. Chen (Huawei)]

In this contribution, a coefficients derivation method based on classification-based mean value is proposed. In the proposed method, the luma template samples are classified into two luma classes by the mean value of them. Correspondingly, two chroma classes are obtained. Then two luma mean values of the two luma classes, and two chroma mean values of the two chroma classes are obtained, respectively. CCLM coefficients are derived based on the two luma mean values and the two chroma mean values. Simulation results reportedly show BD rate on Y, Cb and Cr components for AI configuration over VTM2.0.1 is - 0.07%, 0.05%, and -0.44%, with 100% EncT, 98% DecT;

Study in CE; requires complexity analysis in comparison to the simplified method that was adopted at this meeting. It likely requires more additions than L0191, and potentially two passes to determine the overall luma mean and the class means of luma and chroma. On the other hand, it is significantly less complex than previous CCLM and seems to perform better than L0191.

[JVET-L0651](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4765) Cross-check of JVET-L0342 "CE3-related: Classification-based mean value for CCLM coefficients derivation" [K. Zhang (Bytedance)] [late]

[JVET-L0381](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4478) CE3-related: 4-tap interpolation filter selection with quantization parameter [Y. Kidani, K. Kawamura, K. Unno, S. Naito (KDDI)]

This contribution proposes 4-tap cubic and Gaussian interpolation filter selection with quantization parameter (QP) which is related to Core Experiment 3 (CE3). These filters are applied to JEM-7.0 and are studied in CE3.3 and which filter should be used is selected with intra block sizes and intra directional modes. The thresholds of block size to separate the usage of both filters is kept constant at 8 width or height even though QP values change. In this contribution, the thresholds are proposed to be optimized by versatile QP ranges and the simulation results for this technique reportedly show -0.40%/-0.14%/-0.15% BD-rate for luma gains in AI/RA/LDB, respectively, in the CTC QP range compared to VTM2.0.1 where 2-tap interpolation is applied. Moreover, from the simulation results by versatile QP range, it is confirmed that at high QP range BD-rate for luma in AI increase -0.17% compared to the results with conventional block-sized-based selected filters.

The base proposal CE3.1.1 determines the switching by block and intra mode. Here, the QP is used as additional criterion. Under CTC, the additional gain is around 0.04%. In QP range 32-47, the gain the proposal shows on top of CE3.1.1 becomes larger on average (0.23%), however for class A, where such QP ranges might be applied, there is no gain (even loss for A1). No action.

[JVET-L0520](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4626) Crosscheck for JVET-L0381 [Hendry (Huawei)] [late]

[JVET-L0561](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4671) Crosscheck of JVET-L0381 (CE3-related: 4-tap interpolation filter selection with quantization parameter) [S. Yoo, J. Lim (LGE)] [late]

[JVET-L0515](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4621) CE3-related: Non-zero reference lines padding method on the top-line of CTU [P.-H. Lin, C.-C. Kuo, C.-C. Lin, C.-L. Lin (ITRI)] [late]

This contribution proposes two reference samples padding methods on the top-line of CTU when multiple reference line intra prediction (MRL) is enabled. According to the proposed method, MRL could be used even on the top-line of a CTU without accessing additional pixels outside the current CTU. The results of proposed method 2 show 0.44% and 0.21% gain in AI and RA test conditions respectively. The proposed method could retrieve some gain loss from disabling MRL of CU on the top-line of CTU without obvious encoding and decoding time increasing and unify the parsing process of MRL.

An additional syntax element is sent at CTU boundary, and padding is introducing more operations.

Compared to the method adopted from the CE, the gain is marginal (and even loss in RA for one of the chroma components.

No action.

[JVET-L0537](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4645) Cross-check of JVET-L0515: CE3-related: Non-zero reference lines padding method on the top-line of CTU [X. Ma (Huawei)] [late]

[JVET-L0564](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4674) CE3-related: Joint test of JVET-L0087 and JVET-L0152 for PDPC simplification [M. G. Sarwer, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek), J. Lee, H. Lee, S.-C. Lim, J. Kang, H. Y. Kim (ETRI)] [late]

In this contribution, a simplification of position dependent intra prediction combination (PDPC) is proposed. This contribution combined JVET-L0087 and JVET-L0152. Compared to VTM2.0.1, it is reported that the proposed simplified PDPC can simplify the PDPC with -0.01% (Y), -0.03% (U), and 0.01% (V) BD-rates for AI.

Not worthwhile, as it performs worse than L0152, and L0087 was not adopted anyway

[JVET-L0657](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4771) Cross-check of JVET-L0564 (CE3-related: Joint test of JVET-L0087 and JVET-L0152 for PDPC simplification) [G. Laroche (Canon)] [late]

[JVET-L0630](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4743) CE3-related: Simplification of MDMS derivation [C.-H. Yao, P.-H. Lin, C.-C. Lin, B.-J. Fuh, C.-L. Lin (ITRI)] [late]

This contribution proposes a simplified method of Multiple Direct Mode Signalling (MDMS) to reduce the numbers of pruning checks during the MDMS derivation process by removing +1/-1 derivation. The simulation results show 0.21%, 0.69% and 0.64% coding gain in terms of average BD-rate of Y, Cb, and Cr without any change of the encoding time. Compared to the MDMS (CE3 test 2.4.1), it shows small luma gain (0.01%) with the same encoder complexity.

The complexity compared to CE3 test is not so significantly decreased that it would come to a good tradeoff between implementation and coding benefit

[JVET-L0689](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4803) CE3-related: Comparison of Intra mode coding between L0222 and 3 MPM [B. Wang, A.M. Kotra (Huawei)] [late]

(insert abstract)

Doc was very late – not necessary to review after the decision on 6 MPM.

## CE4 related – Inter prediction and motion vector coding (118)

A BoG coordinated by H. Yang was requested to review contributions in this area.

Contributions in this category were discussed XXday XX Oct XXXX–XXXX (chaired by XXX).

[JVET-L0046](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4127) CE4-related: On line buffer reduction for affine mode [M. Zhou (Broadcom)]

[JVET-L0418](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4516) Crosscheck of JVET-L0046 (CE4-related: On line buffer reduction for affine mode) [H. Chen (Huawei)] [late]

[JVET-L0047](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4128) CE4-related: A clean up for affine mode [M. Zhou, B. Heng (Broadcom)]

[JVET-L0504](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4610) Cross-check of JVET-L0047: CE4-related: A clean up for affine mode [S. Bandyopadhyay (InterDigital)] [late]

[JVET-L0666](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4780) Comparison between JVET-L0047 methods 1 and 2 [F. Le Léannec, F. Galpin (Technicolor)] [late]

[JVET-L0048](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4129) CE4-related: Combined tests of JVET-L0046 and JVET-L0047 [M. Zhou (Broadcom)]

[JVET-L0055](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4136) CE4-related: Redundant Removal for ATMVP [A. Tamse, M. W. Park, S. Jeong, K. Choi (Samsung)]

[JVET-L0456](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4558) Crosscheck of JVET-L0055 on CE4-related: Redundant Removal for ATMVP [T. Ikai (Sharp)] [late]

[JVET-L0068](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4149) CE4-related: Modified LIC [J. Lee, J. Byeon, S. Park, D. Sim (KWU), G. Bang, H. Kim (ETRI)] [late]

[JVET-L0091](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4172) CE4-related: Shared merge list [C.-C. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0582](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4693) Crosscheck of JVET-L0091 (CE4-related: shared merge list) [W. Xu, H. Yang, J. Chen (Huawei)] [late]

[JVET-L0092](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4173) CE4-related: A simplification algorithm for ATMVP [C.-C. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0474](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4578) Cross Check report of JVET-L0092: CE4-related: A simplification algorithm for ATMVP [X. Xu (Tencent)] [late]

[JVET-L0093](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4174) CE4-related: Simplified pruning in merge mode [C.-C. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0555](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4664) Cross-check of JVET-L0093 (CE4-related: Simplified pruning in merge mode) [K. Abe, T. Toma (Panasonic)] [late]

[JVET-L0105](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4186) CE4-related: A second ATMVP candidate [Y.-W. Chen, X. Wang (Kwai Inc.)]

[JVET-L0516](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4622) Crosscheck of JVET-L0105 (CE4-related: A second ATMVP candidate) [N. Zhang (HiSilicon)] [late]

[JVET-L0106](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4187) CE4-related: Modified History-based MVP to support parallel processing [Y.-W. Chen, X. Wang (Kwai Inc.)]

[JVET-L0506](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4612) Crosscheck of JVET-L0106 (CE4-related: Modified History-based MVP to support parallel processing) [L. Zhang (Bytedance)] [late]

[JVET-L0119](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4200) CE4-related: Non-sub-block ATMVP [K. Abe, T. Toma (Panasonic)]

[JVET-L0454](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4556) Crosscheck of JVET-L0119 on CE4-related: Non-sub-block ATMVP [T. Zhou, T. Ikai (Sharp)] [late]

[JVET-L0120](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4201) CE4-related: Low pipeline latency LIC [K. Abe, T. Toma, J. Li (Panasonic)]

[JVET-L0623](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4736) Cross-check of JVET-L0120 "CE4-related: Low pipeline latency LIC" [V. Rufitskiy, A. Filippov, J. Chen (Huawei)] [late]

[JVET-L0144](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4225) CE4-related: Simplified average merge candidate [J. Lee, J. Nam, N. Park, H. Jang, J. Lim, S. Kim (LGE)]

[JVET-L0158](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4239) CE4-related: History-Based Motion Vector Prediction considering parallel processing [N. Park, H. Jang, J. Nam, J. Lee, J. Lim, S. Kim (LGE)]

[JVET-L0525](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4631) Crosscheck report of L0158 (CE4-related: History-Based Motion Vector Prediction considering parallel processing) [B. Choi (Sharp)] [late]

[JVET-L0171](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4262) CE4-related: Merge mode with Regression based Motion Vector Field (RMVF) [R. Ghaznavi-Youvalari, A. Aminlou, J. Lainema (Nokia)]

[JVET-L0187](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4278) CE4-related: Combined P List for Merge Candidate List [L. Xu, F. Chen, L. Wang (Hikvision)] [late]

[JVET-L0543](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4651) Crosscheck for L0187 (CE4-related: Combined P List for Merge Candidate List) [S. H. Wang, S. S. Wang, S. Ma (Peking University)] [late]

[JVET-L0193](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4284) CE4-related: On Affine mode restriction [G. Laroche, J. Taquet, C. Gisquet, P. Onno (Canon)]

[JVET-L0505](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4611) Crosscheck of JVET-L0193 (CE4-related: On Affine mode restriction) [H. Lee, J. Lee, S.-C. Lim, J. Kang (ETRI)] [late]

[JVET-L0194](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4285) CE4-related: On Merge Index coding [G. Laroche, J. Taquet, C. Gisquet, P. Onno (Canon)]

[JVET-L0640](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4753) Cross-check of JVET-L0194 [A. Robert, F. Le Léannec, F. Galpin (Technicolor)] [late]

[JVET-L0197](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4288) CE4-related: Generalized bi-prediction improvements [Y.-C. Su, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-L0513](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4619) Crosscheck of JVE-L0197: CE4-related: Generalized bi-prediction [R.-L. Liao, H. Sun (Panasonic)] [late]

[JVET-L0198](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4289) CE4-related: Simplification of ATMVP candidate derivation [S. H. Wang, S. S. Wang, S. Ma (Peking University), X. Zheng (DJI)]

[JVET-L0600](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4713) Cross-check of JVET-L0198 (CE4-related: Simplification of ATMVP candidate derivation) [X. Xiu (InterDigital)] [late] [miss]

[JVET-L0203](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4294) CE4-related: LIC with reduced memory buffer [P. Bordes, F. Le Léannec, F. Galpin, E. Francois (Technicolor)]

[JVET-L0503](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4609) Cross-check of JVET-L0203: CE4-related: LIC with reduced memory buffer [S. Bandyopadhyay (InterDigital)] [late]

[JVET-L0569](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4679) Crosscheck for L0203 (CE4-related: LIC with reduced memory buffer) [A. Tamse (Samsung)] [late]

[JVET-L0207](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4298) CE4 related: simplified non-sub-block STMVP [F. Le Léannec, T. Poirier, F. Galpin (Technicolor)]

[JVET-L0491](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4597) Crosscheck of JVET-L0207 (CE4 related: simplified non-sub-block STMVP) [L. Zhang (Bytedance)] [late] [miss]

[JVET-L0214](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4305) CE4-related: Motion predictor pruning [A. Robert, F. Le Léannec, F. Galpin, T. Poirier (Technicolor)]

[JVET-L0477](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4581) Crosscheck of JVET-L0214 (CE4-related: Motion predictor pruning) [H. Chen (Huawei)] [late]

[JVET-L0216](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4307) Non-CE4: Parallel Merge Estimation for VVC [S. Esenlik, H. Gao, B. Wang, A.M. Kotra, J. Chen (Huawei)]

[JVET-L0459](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4562) Crosscheck of JVET-L0216 on Non-CE4: Parallel Merge Estimation for VVC [T. Ikai (Sharp)] [late]

[JVET-L0257](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4352) CE4-related: Mismatch between text specification and reference software on clipping the positions of collocated blocks for alternative temporal motion vector prediction (ATMVP) [X. Xiu, Y. He, Y. Ye (InterDigital)]

[JVET-L0625](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4738) Cross-check of JVET-L0257 [H. Jang (??)] [late] [miss]

[JVET-L0259](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4354) CE4-related: Adaptive precision for affine MVD coding [Y. He, X. Xiu, Y. Ye (InterDigital)]

[JVET-L0502](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4608) Crosscheck of JVET-L0259 (CE4-related: Adaptive precision for affine MVD coding) [H. Liu (Bytedance)] [late]

[JVET-L0260](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4355) CE4-related: Affine motion estimation improvements [Y. He, X. Xiu, Y. Ye (InterDigital)]

[JVET-L0536](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4644) Crosscheck of JVET-L0260 (CE4-related: Affine motion estimation improvements) [H. Chen (Huawei)] [late]

[JVET-L0281](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4376) CE4-related: Size constrain for inherited affine motion prediction [H. Huang, W.-J. Chien, M. Karczewicz (Qualcomm)]

[JVET-L0475](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4579) Crosscheck of JVET-L0281 (CE4-related: Size constrain for inherited affine motion prediction) [H. Chen (Huawei)] [late]

[JVET-L0282](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4377) CE4-related: Merge List Simplification [S. Paluri, J. Zhao, S. Kim (LGE)]

[JVET-L0596](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4709) Cross-check of JVET-L0282 [K. Misra (Sharp)] [late]

[JVET-L0296](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4391) CE4-related: encoder speed up and bug fix for generalized bi-prediction in BMS-2.1 [Y. He, J. Luo, X. Xiu, Y. Ye (InterDigital)] [late]

[JVET-L0573](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4683) Crosscheck of JVET-L0296 (CE4-related: Encoder speed-up and bug fix for generalized bi-prediction in BMS-2.1) [Y.-C. Su (MediaTek)] [late]

[JVET-L0300](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4395) CE4-related: Generic Vector Coding of Motion Vector Difference [S. Paluri, M. Salehifar, S. Kim (LGE)]

[JVET-L0613](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4726) Cross-check of contribution JVET-L0300 on Generic Motion Vector Difference Coding [Y. Zhang, W.-J. Chien (Qualcomm)] [late]

[JVET-L0301](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4396) CE4-related: Updated results of BIMVP [B. Choi (Sharp)] [late]

[JVET-L0648](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4762) Crosscheck of JVET-L0301: Improvement of BIMVP [S. Paluri, S. Kim (LGE)] [late]

[JVET-L0302](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4397) CE4-related: History based spatial-temporal MV prediction [X. Xu, X. Li, S. Liu (Tencent)]

[JVET-L0483](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4587) Crosscheck of JVET-L0302 (CE4-related: History based spatial-temporal MV prediction) [C.-C. Chen (MediaTek)] [late]

[JVET-L0305](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4400) CE4-related: History Based Affine Merge Candidate [J. Zhao, S. Paluri, S. Kim (LGE)]

[JVET-L0492](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4598) Crosscheck of JVET-L0305 (CE4-related: History Based Affine Merge Candidate) [L. Zhang (Bytedance)] [late] [miss]

[JVET-L0309](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4404) CE4-related: Simplification to HMVP [J. Zhao, S. Paluri, S. Kim (LGE)]

[JVET-L0493](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4599) Crosscheck of JVET-L0309 (CE4-related: Simplification to History Based Motion Vector Prediction) [L. Zhang (Bytedance)] [late] [miss]

[JVET-L0317](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4412) CE4-related: Sub-block MV clipping in affine prediction [M. Gao, X. Li, M. Xu, S. Liu (Tencent)]

[JVET-L0700](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4814) Crosscheck of JVET-L0317 on Sub-block MV clipping in affine prediction [P. Yin (Dolby)] [late]

[JVET-L0319](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4414) CE4-related: Sub-block MV clipping in planar motion vector prediction [M. Gao, X. Li, M. Xu, S. Liu (Tencent)]

[JVET-L0517](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4623) Crosscheck of JVET-L0319 (CE4-related: Sub-block MV clipping in planar motion vector prediction) [N. Zhang (HiSilicon)] [late]

[JVET-L0320](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4415) CE4-related: affine merge mode with prediction offsets [G. Li, X. Xu, X. Li, S. Liu (Tencent)]

[JVET-L0563](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4673) Crosscheck of JVET-L0320 (CE4-related: affine merge mode with prediction offsets) [T.-H. Li, Y.-C. Yang, Y.-J. Chang (Foxconn)] [late]

[JVET-L0659](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4773) Crosscheck of L0320: CE4-related: affine merge mode with prediction offsets [Y.-W. Chen, X. Wang (Kwai Inc.)] [late]

[JVET-L0322](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4417) CE4 related – constrained model-based affine merge [G. Li, X. Xu, X. Li, S. Liu (Tencent)]

[JVET-L0497](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4603) Cross-check of JVET-L0322 (CE4 related: constrained model-based affine merge) [J. Zhao (LGE)] [late]

[JVET-L0330](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4426) CE4-related: Affine model inheritance from single-line motion vectors [K. Zhang, L. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-L0332](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4428) CE4-related: Adaptive Motion Vector Resolution for Affine Inter Mode [H. Liu, L. Zhang, K. Zhang, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-L0480](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4584) Cross-check of JVET-L0332: Adaptive Motion Vector Resolution for Affine Inter Mode [Y. He (InterDigital)] [late]

[JVET-L0355](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4452) Non-CE4: Enhanced ultimate motion vector expression [T. Hashimoto, E. Sasaki, T. Ikai (Sharp)]

[JVET-L0488](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4593) Cross check of Non-CE4: Enhanced ultimate motion vector expression (JVET-L0355) [M. W. Park (Samsung)] [late]

[JVET-L0371](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4468) CE4-related: Reducing worst case memory bandwidth in inter prediction [H. Chen, H. Yang, J. Chen (Huawei)]

[JVET-L0624](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4737) Cross-check of JVET-L0371 test d [Han Huang, Yu Han (Qualcomm)] [late]

[JVET-L0373](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4470) CE4-related: Unification for affine motion buffer [H. Chen, H. Yang, J. Chen (Huawei)]

[JVET-L0643](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4756) Cross-check of JVET-L0373 "CE4-related: Unification for affine motion buffer" [J. Lee, S. Kim, J. Lim (LGE)] [late]

[JVET-L0389](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4486) CE4-related: Control point MV offsets for Affine merge mode [Y.-C. Yang, Y.-J. Chang (Foxconn)]

[JVET-L0545](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4653) Crosscheck of JVET-L0389 [G. Li (Tencent)] [late]

[JVET-L0390](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4487) CE4-related: Simplification of Affine merge common codebase [Y.-J. Chang, Y.-C. Yang (Foxconn)] [late]

[JVET-L0484](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4588) Crosscheck of JVET-L0390 (CE4-related: Simplification of Affine merge common codebase) [C.-Y. Lai (MediaTek)] [late]

[JVET-L0396](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4493) CE4-related: Affine restrictions for the worst-case bandwidth reduction [L. Pham Van, W.-J. Chien, H. Huang, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-L0587](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4699) Crosscheck of JVET-L0396: Affine restrictions for the worst-case bandwidth reduction [S.Paluri, S. Kim (LGE)] [late]

[JVET-L0400](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4497) CE4-related: Simplification on Non-Adjacent Merge/Skip mode [Y. Han, W.-J. Chien, H. Huang, M. Karczewicz (Qualcomm)]

[JVET-L0401](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4498) CE4-related: Modification on History-based Mode Vector Prediction [W.-J. Chien, Y. Han, H. Huang, M. Karczewicz (Qualcomm)]

[JVET-L0609](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4722) Crosscheck of JVET-L0401 (CE4-related: Modification on History-based Mode Vector Prediction) [Z. Deng, L. Xu (Intel)] [late]

[JVET-L0408](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4506) CE4-related: Improvement on ultimate motion vector expression [J. Li, R.-L. Liao, C. S. Lim (Panasonic)] [late]

[JVET-L0411](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4509) CE4-related: Angular merge prediction [S. Iwamura, S. Nemoto, A. Ichigaya (NHK)]

[JVET-L0565](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4675) Crosscheck of JVET-L0411 (CE4-related: Angular merge prediction) [T.Chujoh (Sharp)] [late]

[JVET-L0425](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4524) CE4-related: History-based MVP without using the last lookup table entry [T. Solovyev, J. Chen, A. Karabutov, S. Ikonin (Huawei)]

[JVET-L0687](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4801) Crosscheck of contribution JVET-L0425 on CE4-related: History-based MVP without using the last lookup table entry [Y. Zhang, W.-J. Chien] [late]

[JVET-L0448](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4547) Constraint of pruning in history-based motion vector prediction [W. Xu, H. Yang, Y. Zhao, J. Chen (Huawei)] [late]

[JVET-L0468](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4572) CE4-related: Fixed sub-block size and restriction for ATMVP [H. Lee, J. Kang, S.-C. Lim, J. Lee, H. Y. Kim (ETRI)] [late]

[JVET-L0588](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4700) Crosscheck of JVET-L0468: CE4-related: Fixed sub-block size and restriction for ATMVP [Y. Han, C.-C. Chen, W.-J. Chien (Qualcomm)] [late]

[JVET-L0470](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4574) CE4-related: Hash-based pruning for merge list construction [T. Solovyev, J. Chen, S. Ikonin (Huawei)] [late]

[JVET-L0522](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4628) CE4-related: simplified constructed temporal affine merge candidates [F. Galpin, F. Leleannec, A. Robert (Technicolor)] [late]

[JVET-L0642](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4755) Cross-check of JVET-L0522: CE4-related: simplified constructed temporal affine merge candidates [X. Xiu (InterDigital)] [late] [miss]

[JVET-L0575](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4685) CE4-related: CTU-level Initialization of History-based Motion Vector Prediction [W. Xu, H. Yang, Y. Zhao, J. Chen (Huawei)] [late]

[JVET-L0601](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4714) Cross-check of JVET-L0408: CE4-related: Improvement on ultimate motion vector expression [T. Hashimoto, T. Ikai (Sharp)] [late]

[JVET-L0602](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4715) Cross-check of JVET-L0330: CE4-related: Affine model inheritance from single-line motion vectors [[T. Hashimoto](mailto:tomonori.hashimoto@sharp.co.jp), [T. Ikai (Sharp)](mailto:ikai.tomohiro@sharp.co.jp)] [late]

[JVET-L0646](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4759) CE4-related: Generalized bi-prediction improvements combined from JVET-L0197 and JVET-L0296 [Y.-C. Su, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek), Y. He, J. Luo, X. Xiu, Y. Ye (InterDigital)] [late]

[JVET-L0663](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4777) Crosscheck of JVET-L0646 (CE4-related: Generalized bi-prediction improvements combined from JVET-L0197 and JVET-L0296) [T.-H. Li, Y.-J. Chang (Foxconn)] [late]

[JVET-L0673](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4787) CE4-related: Combined test of JVET-L0048, JVET-L0273 and JVET-L0281 [H. Huang, W.-J. Chien, H. Wang, L. Van, M. Karczewicz [Qualcomm] [late]

[JVET-L0697](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4811) Cross-check of JVET-L0673 “CE4-related: Combined test of JVET-L0048, JVET-L0273 and JVET-L0281” [[F. Galpin](mailto:franck.galpin@technicolor.com), F. Le Leannec (Technicolor)] [late]

[JVET-L0377](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4474) Rounding Align of Adaptive Motion Vector Resolution [Y. Zhang, C.-C. Chen, H. Huang, Y. Han, W.-J. Chien, M. Karczewicz (Qualcomm)]

[JVET-L0476](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4580) Crosscheck of JVET-L0377 (Rounding Align of Adaptive Motion Vector Resolution) [H. Chen (Huawei)] [late]

[JVET-L0453](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4555) Bugfix for restrictions of bi-prediction for small CUs [Y. Ahn, D. Sim (Digital Insights)] [late]

[JVET-L0469](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4573) Cross-check of JVET-L0453 (Bugfix for restrictions of bi-prediction for small CUs) [S.-C. Lim, J. Kang, H. Lee, J. Lee (ETRI)] [late]

[JVET-L0168](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4259) Motion vector representing bit reduction [H. Jang, J. Nam, S. Kim, J. Lim (LGE)]

[JVET-L0473](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4577) Cross Check report of JVET-L0168: Motion vector representing bit reduction [X. Xu (Tencent)] [late]

[JVET-L0104](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4185) AHG5: Reducing VVC worst-case memory bandwidth by restricting bi-directional 4x4 inter CUs/Sub-blocks [Y.-W. Chen, X. Wang (Kwai Inc.)]

[JVET-L0455](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4557) Crosscheck of JVET-L0104 on AHG5: Reducing VVC worst-case memory bandwidth by restricting bi-directional 4x4 inter CUs/Sub-blocks [T. Zhou, T. Ikai (Sharp)] [late]

[JVET-L0122](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4203) AHG5: Reduction of worst case memory bandwidth [J. Li, R.-L. Liao, C. S. Lim (Panasonic)]

[JVET-L0466](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4570) Crosscheck of JVET-L0122 (AHG5: Reduction of worst case memory bandwidth) [M. Winken (HHI)] [late]

[JVET-L0690](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4804) CE4-related: Affine clean-up and constrained affine inheritance for local and line buffer reduction [H. Huang, W.-J. Chien, H. Wang, M. Karczewicz (Qualcomm)] [late]

Detailed presentation was not requested. The contribution provides information for study.

[JVET-L0694](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4808) CE4-related: Combination of affine mode clean up and line buffer reduction [H. Chen, H. Yang, J. Chen (Huawei), H. Huang, W.-J. Chien (Qualcomm)] [late]

In this contribution, a combination of affine mode clean up (JVET-L0047 method 1) and line buffer reduction (JVET-L0045) with the modification of using the sub-block vectors in the line buffer to do affine inheritance is proposed. It is asserted that these two changes have an interaction, and proposes an adjustment to harmonize the goals of the two schemes at the bottom of CTUs.

It is proposed to use the same sub-block motion vector field for the motion compensation, merge/skip/AMVP list derivation, de-blocking, and storage of the temporal motion vector predictors (TMVPs). The control point motion vectors (CPMVs) are used for the affine motion data inheritance (i.e. for merge mode and affine AMVP mode) if the candidate block is in the current CTU. However, the bottom-left and bottom-right sub-block motion vectors are used for the affine motion data inheritance if the candidate block is in the above CTU. Therefore, no additional line buffer is required to store the CPMVs. It is also proposed to use sub-block MV at bottom-left and bottom-right location for affine data inheritance from above CTU without division by setting the coordinates of bottom-left and bottom-right corner are set to (xNb, yNb+neiH) and (xNb+neiW, yNb+neiH) for inheritance.

This was said to also be easier to specify.

The BD-rate difference was reported to be 0.01% in RA. Decision (harmonization of interaction between adoptions): Adopt.

This was further discussed Wednesday 1115 in Track B (GJS).

After additional study, some participants commented that this seems like a clean approach and will simplify the text, and supported adoption.

[JVET-L0699](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4813) Cross-check of JVET-L0694 “CE4-related: Combination of affine mode clean up and line buffer reduction” [J. Lee, J. Lim, S. Kim] [late]

## CE5 related – Arithmetic coding engine (6)

Contributions in this category were discussed Monday 8 Oct 1545–1700 (chaired by XXX).

[JVET-L0426](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4525) CE5-related: Alternative implementation of CABAC range sub-interval derivation for test CE 5.1.4 [P. Haase, H. Kirchhoffer, S. Matlage, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

This contribution describes an alternative implementation for CABAC range sub-interval derivation, for the state-based probability estimator proposed in JVET-K0430 and was part of CE5 (CE 5.1.4) (JVET-K1025). The proposed method uses a combination of the range-probability product computation and table lookup approaches presented in CE5 (Subtest 2) (JVET-K1025), which means a (1-dimensional) table lookup and a multiplication operation.

Different implementation method which generates the same results as the CE contribution L046? – is included in complexity analysis of BoG

[JVET-L0527](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4633) Crosscheck of L0426 (CE5-related: Alternative implementation of CABAC range sub-interval derivation for test CE 5.1.4) [J. Dong (Qualcomm)] [late]

[JVET-L0429](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4528) CE5-related: lookup table-free implementation of the probability update for tests CE5.1.4 and CE5.1.5 [S. Matlage, H. Kirchhoffer, P. Haase, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

An extension to the stated-based probability estimator presented in JVET-K430 is proposed. The proposed method introduces an optimized transition table and two parameters are added in order to allow for improved control of the state variable update.

Different implementation method which generates the same results as the CE contribution L046? – is included in complexity analysis of BoG

[JVET-L0528](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4634) Crosscheck of L0429 (CE5-related: lookup table-free implementation of the probability update for tests CE5.1.4 and CE5.1.5) [J. Dong (Qualcomm)] [late]

[JVET-L0552](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4661) Training initial CABAC states [F. Bossen (Sharp)] [late]

Initial CABAC states are retrained on the data set defined by common SDR test conditions. A BD rate improvement in the order of 0.2% on average for RA, LB and LP is reported using such retrained initial states. For class D, average gains in excess of 0.5% are reported. Additional experiments include retraining only subsets of the initial states, and recursively retraining a second time. It is suggested to further study the impact of such training on the development of the VVC standard.

Overall gain (luma) 0.04%, 0.18%, 0.23%, 0.20% for AI, RA, LDB, LDP, respectively.

When training only contexts related to coefficients, almost no improvements. This probably explains that the gain for intra is lower.

Effect of retraining is larger when applied to CE5 (fixed window size), but similar to VTM for CE5 (with adaptive window size).

A weighted method was used, such that the results are independent from image size.

It is discussed if it may be beneficial to use training of CABAC initialization regularly with each new VTM to prohibit contributions from using trained elements.

Proponents of new syntax elements likely use some way of training anyway.

If initialization is trained on the current test set, these values should not be used in the final standard.

To prevent overtraining, it could also be investigated if the trained initialization is still beneficial for an independent set of sequences (and there are enough of them available). This could for example be done by comparing the previous set of initializations against the new one with an independent set (sanity check).

The following suggestion was made: Retrain the initializations with the CTC set for each new major version of VTM; verify with an independent set of sequences (tbd ?) / should be large enough that the training is not overtrained (taking the initializations before and after, and see that the deviation of results is not severe on that other set).

Agreed in plenary Wed. 10 Oct. 1400. [Note also in plenary section]

[JVET-L0618](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4731) CE5-related: CE5.1.6 (JVET-L0115) with 10 and 14 bits probability precision for short and long windows [A. Said, J. Dong, H. Egilmez, Y.-H. Chao, M. Karczewicz, V. Seregin (Qualcomm)] [late]

This contribution reduces the probability precision used in CE5.1.6 (i.e., JVET-L0115) from 30 bits to 24 bits. Under the CE5 test conditions, the average coding gains are -0.10% AI, -0.38% RA, and -0.21% LDB. Compared with BMS2.0.1 VTM configuration, the average coding gains are -1.02% AI, -0.88% RA, and -0.81% LDB.

The performance drop in RA is 0.05% on average.

Is included in complexity analysis of BoG

[JVET-L0655](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4769) Crosscheck of JVET-L0618 (CE5-related: CE5.1.6 (JVET-L0115) with 10 and 14 bits probability precision for short and long windows) [C.-M. Tsai (MediaTek)] [late]

[JVET-L0638](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4751) CE5-related: Retraining of context initialization values for CE5.1.4 [H. Kirchhoffer, C. Bartnik, P. Haase, S. Matlage, J. Stegemann, D. Marpe, H. Schwarz, T. Wiegand (HHI)] [late]

New context model initialization values are proposed for tests CE5.1.4.1 and CE5.1.4.2 (naming is according to the CE5 summary report JVET-L0025). Both tests use the state-based probability estimator of JVET-K0430 using an 8 and a 12 bit state variable per context model. CE5.1.4.1 doesn’t use custom window sizes, CE5.1.4.2 uses custom window sizes. Only the initialization values for the states are updated in this proposal (not the custom window size parameters). When comparing both CE tests (using new initialization values) to VTM-2.0.1 (using new initialization values), the advantage in Luma coding gain of CE5.1.4.2 (with custom window sizes) over CE5.1.4.1 (without custom window sizes) is only 0.06% for AI, 0.10% for RA, and 0.10% for LB.

Similar to results of L0552 in terms of VTM (though a different training procedure was used), and also unveils that the customized window sizes have less effect when better initialization is used. Conceptually, it is somehow obvious that one aspect of customized window sizes is that they only have effect if a correct customization is used.

## CE6 related – Transforms and transform signalling (28)

Contributions in this category were discussed Monday 8 Oct 1720–2020 (chaired by JRO).

[JVET-L0059](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4140) CE6-related: Simplification on MTS kernel derivation [K. Choi, K. P. Choi (Samsung)]

This contribution presents a simplification of MTS by removing a dependency between the number of non-zero coefficients and a kernel selection of MTS. MTS in VTM2.0 uses the number of non-zero coefficients to select kernels adaptively in intra mode. If intra and the number of nonzero coefficients is less than two, DST7 kernel is always used both horizontally and vertically. Otherwise, DST7 and DCT8 are evaluated through RDO process to apply transform. The proposed simplification in this contribution is to remove the dependency between the number of non-zero coefficients and a kernel for MTS. Testing results on the proposed method show no BD rate loss on average for All Intra (AI), Random Access (RA), Low Delay B (LDB), and Low Delay P (LDP) configurations, respectively, compared to VTM-2.0.1, and 0.1% loss for AI and no BD rate loss on average for RA, LDB, and LDP configurations, respectively, compared to BMS-2.0.1.

Unification of conditions intra and inter is desirable.

Other proposal targeting that issue: L0395, which is however mainly targeting other aspects and unifies ia way that is not simplified.

Decision: Adopt JVET-L0059.

[JVET-L0494](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4600) Crosscheck of JVET-L0059: (CE6-related: Simplification on MTS kernel derivation) [X. Zhao (Tencent)] [late]

[JVET-L0060](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4141) CE6-related: Unified matrix for transform [K. Choi, K. P. Choi (Samsung)]

Was reviewed in BoG L0685.

[JVET-L0495](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4601) Crosscheck of JVET-L0060: (CE6-related: Unified matrix for transform) [X. Zhao (Tencent)] [late]

[JVET-L0111](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4192) CE6-related: Transform Skip Condition on Transform Block size [Jeeyoon Park, Byeungwoo Jeon (SKKU)] [late]

This contribution reports that the transform skip (TS) condition in VTM-2.0.1 (TS is possible when the product of TU width and height is equal to or less than 16) does not match with that in VVC draft 2 (TS is possible when both TU width and height are equal to or less than 4), and provides performance comparison of the two different conditions. With VTM-2.0.1 as the anchor, the condition in VVC draft 2 shows that an average of Y(0.00%), U(-0.01%) and V(0.01%) coding gain for AI with run-time change of encoder (76%) and decoder (82%), respectively.

Run time is not reliable, as only chroma in case of separate tree would be affected.

The draft text specifies that TS is allowed for block sizes 2x2, 2x4, 4x2 and 4x4. The software furthermore allows it for 8x2 and 2x8.

Decision (BF/SW): Adopt JVET-L0111

[JVET-L0134](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4215) CE6-related: Shape adaptive transform selection [J. Lainema (Nokia)]

This contribution proposes a tool that selects the horizontal and vertical transforms for intra blocks based on the shape of the transform block. For square blocks the proposed tool selects DCT2 for both directions. For non-square blocks DST7 is used for the direction of shorter dimension of the block and DCT2 is used for the direction of the larger dimension. In the case multiple transform selection (MTS) is enabled, the shape adaptiveness is applied when MTS flag is zero and VTM-2 would use DCT2 for both horizontal and vertical directions. In the case MTS flag is one, the VTM-2 transform selection process is followed.

The proposed tool provides -1.17 %, -0.47 % and -0.09 % bitrate impact for AI, RA and LDB configurations, respectively when MTS is off. When MTS is on, the bitrate impacts are -0.13 %,   
-0.01 % and -0.01 %, respectively.

Applied to both luma and chroma.

Encoder run time increases by 6% for AI, likely due to the fact that DST-7 computation is slower.

Chroma loss in RA and LDB. There is another result which applies the method only to intra blocks in inter slices with less chroma loss.

Further study in CE.

Another option might be to make context coding of MTS dependent on block shape.

[JVET-L0149](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4230) CE6-related: Complexity reduction method based on skipping high frequency coefficients for inter MTS [M. Koo, M. Salehifar, J. Lim, S. Kim (LGE)]

In the current VTM, coefficient region other than top-left 32x32 is skipped (zeroed-out) for inter predicted residual when inter MTS is turned on.

In this contribution, the following three restrictions (RMTS\_1, RMTS\_2, and RMTS\_3) based on the skipping with inter MTS on are proposed, all of which are stronger than the current one:

1. RMTS\_1

* If height ≥ width && height ≥ 16, then (width, height/2) region is kept.
* If width > height && width ≥ 16, then (width/2, height) region is kept.

1. RMTS\_2: If width (height) ≥ 32, then left (top) half of coefficients are kept.
2. RMTS\_3: If width (height) ≥ 16, then left (top) half of coefficients are kept.

The experimental results of the above three methods are summarized as follows:

1. RMTS\_1: 96%/100% (RA), and 95%/99% (LD) encoding/decoding time compared to VTM anchor, BD-rate degradation is 0.06% (RA), and 0.12% (LD).
2. RMTS\_2: 96%/98% (RA), and 96%/98% (LD) encoding/decoding time compared to VTM anchor, BD-rate degradation is 0.03% (RA), and 0.03% (LD).
3. RMTS\_3: 94%/99% (RA), and 92%/97% (LD) encoding/decoding time compared to VTM anchor, BD-rate degradation is 0.08% (RA), and 0.18% (LD).

It is suggested to normatively specify that certain transform coefficients are set to zero. Such an approach should not be specified, as certain video sequences may need them (and in particular at lower QPs). Encoder speedup could also be achieved in a non-normative way, but then likely the loss would be higher,

[JVET-L0559](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4669) Cross-check of L0149 [K. Choi (Samsung)] [late]

[JVET-L0190](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4281) CE6-related: Simplification of Intra 4-Point Multiple Transforms Selection [J. An, Y.-C. Sun, J. Lou (Alibaba)]

This contribution proposes to use only DST7 for intra luma 4-point transform when the MTS\_CU\_flag is equal to 1, the experiments results show that there is 10% encoding time reduction with 0.0% BD-rate change.

This introduces inconsitency between inter and intra, and makes MTS signalling dependent on block size which is undesirable.

With encoder only change it would result in 0.2% BR increase in AI.

No action.

[JVET-L0631](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4744) Cross-check of contribution JVET-L0190 on Simplification of Intra 4-Point Multiple Transforms Selection [Y. Zhang, H. Huang (Qualcomm)] [late]

[JVET-L0195](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4286) CE6-related: MTS for non-square CUs [J. Jung, D. Kim, G. Ko, J. Son, J. Kwak (WILUS), Y. Lee (Humax)]

This contribution proposes to apply MTS (Multiple Transform Selection) for large rectangular CUs. Currently, MTS is applied to a luma block only when both of the width and the height of the block is smaller than or equal to 32. It is proposed to loosen the restriction to apply MTS to the horizontal if the width is smaller than or equal to 32 even though the height is larger than 32, and vice versa. Compared with the current reference software, large rectangular blocks such as 64xN and Nx64 can exploit selection of the transform kernels among DST-VII and DCT-VIII. Experimental results show that the proposed method achieves 0.00% (AI), -0.04% (RA) and -0.02% (LD) BD-rate with slightly increased encoding time compared to BMS-2.0.1 with VTM configuration. Especially, 0.14% BD-rate gain is observed for 4K resolution test sequences in class A1 with RA configuration. When MTS is enabled for inter coded blocks, experimental results show 0.00% (AI), -0.06% (RA) and -0.05% (LD) BD-rate compared to BMS-2.0.1 with VTM configuration. Experimental results on the proposed method with both the maximum BT size and the maximum TT size equal to 64 show -0.09% (AI), -0.07% (RA) and -0.04% (LD) BD-rate compared to BMS-2.0.1 with VTM configuration.

Similar approach as one aspect of L0395, where it is one of the tests in CE.

[JVET-L0579](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4689) Cross-check of JVET-L0195 (CE6-related: MTS for non-square CUs) [Bumshik Lee (Chosun Univ.)] [late]

[JVET-L0264](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4359) CE6-related: Removed MTS CU-Flag and Reduced MTS Pairs [K. Naser, F. Galpin, T. Poirier (Technicolor)]

In this contribution, it is proposed to reduce the number of possible pairs of horizontal and vertical transforms in the MTS design from four to three. Indeed, it is reportedly observed that among the four transforms pairs of the current MTS design, the last pair is rarely used. This contribution proposes to remove the last pair and to augment the three remaining pairs with the core transform DCT2 for vertical and horizontal coding. By doing so, it is asserted that the MTS CU-flag does not need to be coded anymore; which removes one context. This reportedly results in simplification in both the encoder and decoder designs. Two tests are reported to be performed. Test1 replaces the pair (DCT8,DCT8) by (DCT2,DCT2) and removes the MTS flag. Test2 proposes a variant, with in addition an intra mode dependent transforms set mapping as used in the JEM AMT design. The encoder time is reported to be reduced to 93-96% compared to the VTM2 anchor for both tests. Test1 is reported to provide BD-rate variations of -0.02% in AI, 0.07% in RA. Test2 is reported to provide BD-rate variations of -0.04% in AI, 0.06% in RA. A BD-rate variation of -0.10% AI, -0.09% RA is also observed in class F with Test2.

DCT-8 seems useful for inter coding.

No action.

[JVET-L0496](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4602) Crosscheck of JVET-L0264: (CE6-related: Removed MTS CU-Flag and Reduced MTS Pairs) [X. Zhao (Tencent)] [late]

[JVET-L0289](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4384) CE6-related: Unification of Transform Skip mode and MTS [X. Zhao, X. Li, S. Liu (Tencent)]

This contribution presents a method to unify Transform Skip (TS) mode and Multiple Transform Selection (MTS). By replacing 4-point DCT-8 with Identity Transform (IDT) and merging the syntax of TS mode with MTS, TS mode is included as part of MTS. On top of VTM-2.0.1 with inter MTS enabled, it is reportedly shown that an average of -0.05%, -0.02% and -0.07% coding gain is achieved for AI, RA and LDB, respectively, with almost no run-time change, and the coding gains on Class F sequences are -0.25%, -0.47% and -0.51% for AI, RA and LDB, respectively.

For chroma, TS flag is removed as well, which might need to be re-invoked later.

In RA, similar results when inter MTS is enabled.

Relative small gain for CTC.

The approach of identity transform allows making TS selective 1D or 2D (as it was in JEM), and therefore might be desirable. On the other hand, not using DCT-8 for block length 4 and disallowing transform skip for chroma introduces other specific constraints, which may not be justified by the small gain (in particular, as it is likely that more changes will be done in MTS, it is still a moving target even in terms of transform bases investigated in CE).

No action at this point.

[JVET-L0683](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4797) Cross-check of JVET-L0289 (CE6-related: Unification of Transform Skip mode and MTS) [K. Choi (Samsung)] [late]

[JVET-L0304](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4399) CE6-Related: Multiplication Free Transform [M. Salehifar, M. Koo, S. Paluri, J. Lim, S. Kim (LGE)]

This contribution proposes multiplication free transform which consists of only additions (subtraction) and shifts, which could be applied for any transform including MTS candidates. The proposed technique is tested with different maximum number of the allowable terms for the shifts and additions. In particular it is tested with: 1) Allowing 5 terms of shifts, 2) Allowing 4 terms of shifts, and 3) Allowing 3 terms of shifts.

As first test results with allowing maximum 5 terms of shifts compare to VTM anchor, has identical performance.

As second test results with allowing maximum 4 terms of shifts compare to VTM anchor, BD-rate difference of 0.00% (AI), 0.01% (RA), and -0.01% (LDB) is observed.

As third test results with allowing maximum 3 terms of shifts compare to VTM anchor, BD-rate difference of 0.11% (AI), 0.05% (RA), and -0.01% (LDB) is observed.

Was discussed in BoG L0685

[JVET-L0597](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4710) CE6-related: cross-check report of JVET-L0304 on Multiplication Free Transform [E. François, K. Naser (Technicolor)] [late]

[JVET-L0331](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4427) CE6 related: On Index Signalling of Multiple Transform Selection [L. Zhang, K. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

In VTM2.0, Multiple Transform Selection (MTS) is employed wherein a block could adaptively select transform matrices from a set of transform matrices. The index of selected transform matrix is signalled to the decoder side. To save the bits due to index signalling, for an intra-coded block, if there are less than 3 non-zero coefficients, the index signalling is skipped and default transform matrices are used implicitly. A counter is required to record how many non-zero coefficients are available within one coding unit which increases the burden of parsing process. In this contribution, the counter is replaced by the position of the last non-zero coefficient. Simulation results reportedly show that proposed method has no BD rate changes for All Intra configurations but both encoding and decoding time are reduced.

Still has different operation for intra and inter

Marginal gain for LDB

Replace the counting by threshold on last coefficient position.

JVET-L0059 has more simplification without additional check, and unifies inter and intra additionally.

No action on L0331

[JVET-L0334](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4430) AHG 16: Transform-free coding for 2×N or N×2 chroma blocks [K. Zhang, L. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

In this contribution, no transform/inverse-transform is required for tiny blocks with sizes 2×N or N×2. The 2-point transform could be removed accordingly. Two solutions are provided. In the first solution, tiny blocks are always coded with all residues equal to 0. In this case, the 2×2 coding group scan is also removed. In test 2, tiny blocks are always coded with the transform-skip mode. In test 1, simulation results reportedly show 0.06%/1.55%/1.76% and 0.11%/3.31%/3.57% BD-rate changing on Y/Cb/Cr components for All Intra (AI) and Random Access (RA) configurations, respectively, in average compared with VTM-2.0.1. Meanwhile, it reports encoder running time is also reduced by 2%. In test 2, simulation results reportedly show 0.11%/1.40%/1.58% and 0.13%/2.92%/3.10% BD-rate changing on Y/Cb/Cr components for AI and RA configurations, respectively.

Implicitly enforcing zero coding is not appropriate in particular in the low QP range.

The loss in chroma is relative large (and even reflected in luma loss, as the bit rate is apparently increased).

Generally, length 2 transform is not critical in complexity.

No action.

[JVET-L0535](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4643) Crosscheck of L0334: AHG 16: Transform-free coding for 2×N or N×2 chroma blocks [Y.-W. Chen, X. Wang (Kwai Inc.)] [late]

[JVET-L0634](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4747) Cross-check of L0331 (CE6 related: On Index Signalling of Multiple Transform Selection) [S. Paluri, S. Kim (LGE)] [late]

[JVET-L0353](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4450) CE6-related: MTS using DST-4 and transposed DCT-2 [Y. Lin, J. Zheng, Q. Yu, N. Zhang (HiSilicon), C. Zhu (UESTC)]

Was presented in BoG L0685

[JVET-L0560](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4670) Cross-check of JVET-L0353 (CE6-related: MTS using DST-4 and transposed DCT-2) [K. Abe, T. Toma (Panasonic)] [late]

[JVET-L0395](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4492) CE6-related: MTS with 4-point DST/DCT-4 and large block support [H. Egilmez, A. Gadde, V. Seregin, M. Karczewicz, A. Said (Qualcomm)]

This contribution presents test results for enabling MTS for inter CUs with the flowing modifications: for CU’s side length of 64 DCT-2 transform is used without signalling, MTS is not applied to 4x4 inter CUs, intra coefficient threshold based signalling is applied for inter MTS indices, encoder fast methods are applied. The experimental results show that the proposed changes provide 0.16%, 0.44% and 0.66% average luma BD-rate gains over VTM 2.0.1 under AI, RA and LDB configurations.

Unifying inter and intra, but check on number of coefficients is now also applied on inter (but no separate results on that, so it cannot be directly compared to L0331 and L0059). The other aspects are modifications of transforms, which are rather deviating from the goal of unifying the transforms (applying different transforms for 4xN/Nx4 blocks, and applying MTS also to smaller smaller side in case of Nx64 and 64xN). The main gain comes from the different transforms. Investigate the latter aspects in CE in terms of their additional benefit. Enabling the Nx64 would come at no additional implementation complexity at the decoder.

[JVET-L0599](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4712) Crosscheck of JVET-L0395: (CE6-related: MTS with 4-point DST/DCT-4 and large block support) [X. Zhao (Tencent)] [late]

[JVET-L0407](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4505) CE6-related: Transform skip for 2x2 chroma blocks and disable 2x2 chroma blocks in intra slices [L. Pham Van, W.-J. Chien, V. Seregin, T. Hsieh, M. Karczewicz (Qualcomm)]

This contribution proposes two modifications for 2x2 chroma blocks. The first modification is to disable 2x2 chroma blocks in intra slice. The second modification is to force 2x2 chroma blocks to be coded in transform skip mode. The first method reportedly leads to an average [Y, U, V] BD-rate change of (0.00%, 0.05%, 0.09%) for VTM AI configuration. It is also reported an average [Y, U, V] BD-rate change of (0.01%, 0.13%, 0.19%) and (-0.03%, -0.01%, -0.13%) for RA and LB configurations, respectively for the combination of the two proposed techniques.

The aspect of small block sizes is studied in a more general way (AHG, see CE1 related contributions). It is not that critical under the aspect of transforms, rather relates to prediction. Likewise, the enforcing of TS in inter slices for 2x2 blocks is not giving a complexity advantage (as the length 2 transform is very simple), and rather has chroma BD loss.

No action.

[JVET-L0421](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4520) CE6-related: fast implementation of MTS transforms using matrix multiplication [K. Naser, G. Rath, E. François (Technicolor)] [late]

The current MTS design considers the two additional transforms of DST-7 and DCT-8. Compared to DCT-2, they cannot be decomposed into partial butterfly representation. Although there exist some recent proposals to speed-up the implementation of DST-7 and DCT-8, they are generally specific to each transform size, and they contain several un-repeated and non-generic operations, which is asserted to reduce the possibility of optimal parallelization. This contribution proposes to decompose the MTS transforms basis into smaller matrices and to perform matrix multiplication to implement the transforms. The proposed approach is reported to be generic, independent from the transform size, and SIMD implementation friendly. Compared to a full matrix multiplication approach of VTM2 MTS transforms, the proposal is reported to significantly reduce the required memory (5% of the full matrices memory need) and the number of operations (number of multiplications reduced by 5 to 6). It is also reported that the proposed implementation has no impact on the coding performance.

DFT stages are matrix multiplications that use 10-bit integer.

No analysis if it is less complex than fast MTS implementation that were investigated in CE6, not clear that it is better. Further, more unified transform design is more desirable than fast alg. For specific MTS.

In terms of computation time, saving is not so large compared to full matrix.

In an updated version information was provided that the approach might require less computations relative to the methods investigated so far in CE6.

[JVET-L0650](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4764) Cross-check of JVET-L0421 (CE6-related: fast implementation of MTS transforms using matrix multiplication) [late] [M. Salehifar (LGE)] [late]

[JVET-L0489](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4594) CE6-related: Transform Simplification [C. Hollmann, P. Wennersten, J. Ström, R. Sjöberg (Ericsson)] [late]

This contribution investigates the trade-off between encoding run time and BD rate gain for the Multiple Transform Selection (MTS) tool. The main idea is to avoid testing DCT-8 in MTS. In a first test it is claimed that a non-normative (encoding-only) change can reduce the encoding run time to 62% for AI and 91% for RA, while increasing BD-rate by 0.38% for AI (MTS gain was about -3.3%) and 0.20% for RA (MTS gain was about -2.0%). In a second test it is claimed that a normative change to the decoder can reduce the encoding run time similarly; to 62% / 89% / 95% for AI/RA/LD. It is asserted that in this second test the BD rate figures increase less; 0.30% for AI (MTS gain was about -3.3%), 0.13% for RA (MTS gain was about -2.0%) and 0.05% for LD (MTS gain was about -1.3%). It is proposed that the group adopts the non-normative change and studies how to best utilize DCT-8 in a CE.

Normative change should not be done, as a smarter encoder might use the gain that comes from the remaining transforms

Non-normative change introduces relatively large loss (considering that we adopted other intra coing tools which just give 0.4% or less).

Better ways of reduction (e.g. omitting certain transforms from encoder search for small block sizes, certain shapes of blocks, etc.) might be better solutions for fast algorithms.

No action.

[JVET-L0652](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4766) CE6-related: Combination test of CE 6-1.2-b and CE 6-2.1-a [[Y. Zhao](mailto:yin.zhao@huawei.com), H. Yang, J. Chen (Huawei), M. Koo, M. Salehifar, J. Lim, S. Kim (LGE)] [late]

This contribution reports combination tests between following two tests:

1. CE6-1.2-b: spatially varying transform (SVT)
2. CE6-2.1-a: simplified MTS with reduced secondary transform

When inter MTS off, the observed BD-rate changes are -1.02% (AI), -1.19% (RA), and encoding time/decoding time is 94%/97% (AI), 114%/101% (RA). When inter MTS on, it is observed that BD-rate changes are -1.02% (AI), -1.07% (RA) and encoding time/decoding time is 94%/97% (AI), 111%/100% (RA).

Additional information - no action

[JVET-L0682](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4796) CE6-related: Low-complexity approximations with 8-bit Transform Adjustment Filters (TAF) [H. Egilmez, Y.-H. Chao, A. Said, V. Seregin, M. Karczewicz (Qualcomm)] [late] [miss]

This contribution reports results for an 8-bit version of the unified transformation approach approximating the DCT-8 and DST-7 in CE6.1.6, where each transform is approximated with an adjustment filter as pre-processing and inverse of DCT-2.

The results show less than 0.xx% coding gain loss in BD rate as against the VTM-2.0.1 anchor.

Partial results – likely average will be <0.1% loss compared to the method tested in 6.1.6a (where 9-bit adjustment filters and 10-bit DCT-2 was used). An additional shift is performed to guarantee 16-bit overall implementation.

Another expert expresses that another clipping step might be necessary before the DCT-2 to guarantee 16-bit implementation. Behaviour in lower QP ranges should also be studied.

Further study in CE

## CE7 related – Quantization and coefficient coding (21)

Contributions in this category were discussed Monday 8 Oct 2020–2145 (chaired by JRO).

[JVET-L0095](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4176) CE7-related: Modified dequantization scaling [S.-T. Hsiang, S.-M. Lei (MediaTek)]

In VCC WD 2, when the size of a transform block is not a power of 4, the values of the transform coefficient levels shall be further scaled by a normalization factor equal to 1/sqrt(2). The number of fractional bits is such further increased by 8 for the scaling process. In this contribution, the scaling process on transform coefficient levels by a dequantization scaling factor and a normalization scaling factor is replaced by one scaling operation using a 2x6 look-up table. The number of fractional bits for the scaling process by the proposed method is reportedly kept the same as that of HEVC when the 6 fractional bits are employed for representing the entry values of the proposed look-up table. The proposed dequantization scaling method reportedly leads to -0.03%, 0.00%, and -0.03% average luma BD-rates for the AI, RA, and LB, respectively, under the VTM2.0.1 common test conditions (CTCs).

Targeting complexity reduction rather than compression efficiency

The current specification of VVC was written with the intent to inherit as much as possible the HEVC method (where due to square blocks the scaling factors always relate to powers of 4

It is mentioned in the discussion that other methods would be possible even without LUT (“QP-3” approach still in the VTM software but disabled)

The proposal saves some pseudocode but introduces more LUT values

In terms of processing, this is not critical

No action.

[JVET-L0567](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4677) Crosscheck for L0095 (CE7-related: Modified dequantization scaling) [A. Tamse (Samsung)] [late]

[JVET-L0096](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4177) CE7-related: Context modeling of the position of last significant coefficient coding [M. G. Sarwer, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

This contribution presents a context modelling method to code the position of the last significant coefficient of the coding block (CB). In this proposal, both x and y co-ordinate of the position of last coefficient share same context variables under certain conditions. This proposal reduces the number of context variables to code last\_sig\_coeff\_x and last\_sig\_coeff\_y syntax elements from 48 to 34 with 0.01% (Y), 0.05% (U), and 0.09 % (V) BD-rates for RA.

Not important currently to reduce the number of contexts.

Keep in mind if it should become necessary later in the development.

[JVET-L0501](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4607) Crosscheck for JVET-L0096 (CE7-related: Context modeling of the position of last significant coefficient coding) [L. Li (LGE)] [late]

[JVET-L0097](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4178) CE7-related: Context modeling using quantization index for dependent quantization [Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

In the dependent quantization, it is proposed to use quantization index for context modeling. Using quantization index for context modeling can remove the state transition process for de-quantization. Therefore, parallel de-quantization can be applied in hardware implementation. Simulation results reportedly show negligible impact on coding efficiency.

Several experts express that it is not obvious that there is a problem that needs to be solved.

No action.

[JVET-L0639](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4752) Cross-check for JVET-L0097 [M. Gao (Tencent)] [late]

[JVET-L0121](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4202) CE7-related: Support of quantization matrices [T. Toma, K. Abe (Panasonic)]

This contribution proposes to support quantization matrices in VTM. The proposed quantization matrices are HEVC based method with extension to support rectangular CU. This method is implemented in VTM 2.0.1 and improvement of subjective quality that is introduced by the quantization matrices is shown.

There is no doubt that quantzation matrices will be needed in VVC, as they are commonly used in products. The approach that is suggested here is a straightforward of the HEVC method of signalling to the case of non-square blocks. However, several aspects require further study:

- Do the different MTS basis function sets require different matrices? E.g. the meaning of the DST-7 coefficients is different from the DCT-2 coefficients in terms of frequency. Another could be to dtermine a way of deriving a matrix for another transform from the one of DCT-2

- Is it really necessary to specify default matrices, as practically mostly customized matrices are used.

AHG study (put under mandates of AHG10)

[JVET-L0500](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4606) Crosscheck of JVET-L0121 (CE7-related: Support of quantization matrices) [M. Ikeda (Sony)] [late]

[JVET-L0145](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4226) CE7-related: Constraints on context-coded bins for coefficient coding [T.-D. Chuang, S.-T. Hsiang, Z.-Y. Lin, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

In the VTM2.0.1 coefficient coding, the averaged maximum number of context-coded bins per 16 samples is 256% of that in HEVC. In this contribution, it is proposed to constrain the maximum number of context-coded bins to 30 for luma 4x4 sub-blocks, 16 for chroma 4x4 sub-blocks, and 4 for chroma 2x2 sub-blocks. The averaged maximum number of context-coded bins per 16 samples is reduced to 101.3% of that in HEVC. The constraints on the maximum number of context-coded bins per coefficient sub-block are increased according to the last significant sub-block position without increasing the worst-case averaged maximum number of context-coded bins per 16 samples. To improve the parsing throughput and reduce the number of coding passes, greater than 2 flags are moved to the first coding pass after the parity bit. The proposed method is implemented on top of CE7.1.3.b. The simulation results reportedly show that, the average luma BD-rates are -0.18%, -0.06%, and -0.19% in AI, RA, and LB cases respectively, and the average chroma BD-rates are 0.08%, 0.18%, and 0.08% in AI, RA, and LB cases respectively.

Further study in CE.

[JVET-L0603](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4716) Crosscheck of JVET-L0145: CE7-related: Constraints on context-coded bins for coefficient coding [Y.-C. Sun (Alibaba)] [late]

[JVET-L0146](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4227) CE7-related: Context variable reduction for coefficient coding [Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

In this contribution, it is proposed to reduce context variables for dependent quantization. The add operation to derive the context variable index is also removed. In test1, the number of context variables for significant flag, parity flag, and greater flags are reduced to 74%. In total 48 context variables are saved, which results in 0.09%, 0.11% and 0.18% luma BD-rates with negligible encoding time and decoding time changes for AI, RA, and LB, respectively, compared against VTM2.0.1. In test2, the number of context variables for significant flag, parity flag, and greater flags are reduced to 63%. In total 68 context variables are saved, which results in 0.19%, 0.16% and 0.26% luma BD-rates with negligible encoding time and decoding time changes for AI, RA, and LB, respectively, compared against VTM2.0.1.

Two additional results combining this proposal and context reduction for the position of the last coefficient in JVET-L0096 are provided. Based on the test1, 62 context models are reduced. The combined test results in 0.12%, 0.13% and 0.17% luma BD-rates with negligible encoding time and decoding time changes for AI, RA, and LB, respectively, compared against VTM2.0.1. Based on the test2, 82 context models are reduced. The combined test results in 0.23%, 0.18% and 0.28% luma BD-rates with negligible encoding time and decoding time changes for AI, RA, and LB, respectively, compared against VTM2.0.1.

Reduction of context models is not of prior importance, as it does not harm too much complexity. Here, it would result in loss.

No action.

[JVET-L0531](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4639) Crosscheck of L0146: CE7-related: Context variable reduction for coefficient coding [Y.-W. Chen, X. Wang (Kwai Inc.)] [late]

[JVET-L0276](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4371) CE7-related: Analysis of padding bytes for VTM-2 [H. Schwarz, T. Nguyen (Fraunhofer HHI)]

(include abstract)

No need for presentation, information document, related to adoption L0274.

[JVET-L0316](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4411) CE7-related: Reduced context models for transform coefficients coding [M. Gao, X Li, S. Liu (Tencent)]

This contribution proposes to reduce the context models for transform coefficients by sharing the context models among the transform coefficients. It is reported that the proposed method can save 12 context models in total, while keeping similar coding performance to VTM2.0.1. More specifically, the BD rate increase of the proposed method is reported as 0.02%, 0.02%, 0.02% for AI, RA and LD configurations, respectively. Another method is also proposed on the top of the first method, which can save 54 context models and the BD-Rate increase is reported as 0.05%, 0.04% and -0.04% for AI, RA and LD, respectively.

Presented in track B Wed 1620 (chaired by JRO).

As it is planned to retrain context initialization, the situation might change. Also when any adoptions from CE5 would be made, the situation might change. Minor tweaks such as reducing or unifying cntext models would be more appropriate at a later stage of standardization.

No action at this moment.

[JVET-L0577](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4687) Crosscheck of JVET-L0316 (CE7-related: Reduced context models for transform coefficients coding) [C.-M. Tsai (MediaTek)] [late]

[JVET-L0695](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4809) Crosscheck of JVET-L0316 [T. Nguyen (HHI)] [late]

[JVET-L0325](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4421) CE7-related: High throughput coefficient coding depending on the sub-block size [J. Choi, J. Heo, S. Yoo, J. Choi, J. Lim, S. Kim (LGE)]

This contribution targets on improving throughput of the arithmetic coding engine by reducing the number of context coded bins for coefficients level coding. Specifically, in the proposed method, the number of worst case context coded bins is controlled by the sub-block size to support the number of worst case context coded bins per pixel is supported in same manner because current VTM 2.0.1 allows two sub-block sizes (4x4 and 2x2). Six tests with various number of constraint values are proposed to find the best trade-off of throughput and performance. The maximum luma BD rate savings are 0.17% for AI, 0.07% for RA, and 0.12% for LD. It is further reported that all the modules and processes of current arithmetic coding engine are kept unchanged and no additional module is needed in the proposed approaches.

Note that Test #4 is a part of CE7.1.3b which was adopted. Specifically, Test #4 is identical to CE7.1.3b except rice parameter initialization.

Presented in track B Wed 1620 (chaired by JRO).

Exactly the same as CE7.1.3b. No additional action.

[JVET-L0570](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4680) Cross check of CE7-related: High throughput coefficient coding depending on the sub-block size (JVET-L0325) [M. W. Park (Samsung)] [late]

[JVET-L0328](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4424) CE7-related: modified binarization for reduced bin-to-bit ratio [F. Bossen (Sharp)]

A modified coefficient level coding method is proposed. It is asserted that it results in fewer bins on average, as observed by a reduction of CABAC padding bytes. Average RD performances compared to VTM 2.0.1 are −0.25% / −0.16% / −0.29% / −0.21% for AI / RA / LB / LP configurations. Larger improvements, up to about 3%, are observed for cases where a lot of padding occurs in VTM.

Presented in track B Wed 1620 (chaired by JRO).

Most of the aspects are already covered by the adoption in 7.1.3b. The contribution gives more information where the gain comes from, and also points out that certain sequences obviously generate more padding bytes than other. No further specific action.

[JVET-L0605](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4718) Crosscheck of JVET-L0328 (CE7-related: modified binarization for reduced bin-to-bit ratio) [S. Yoo, S. Kim (LGE)] [late]

[JVET-L0402](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4499) CE7-related: Complexity reduction of significance map coding and bypass of greater than 4 flags [C. Auyeung, J. Chen (Huawei)]

No need to be presented according to proponent.

[JVET-L0542](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4650) Cross check of JVET-L0402 (CE7-related: Complexity reduction of significance map coding and bypass of greater than 4 flags) [H. Schwarz (Fraunhofer HHI)] [late]

## CE8 related – Current picture referencing (8)

Contributions in this category were discussed XXday XX Oct XXXX–XXXX (chaired by XXX).

Assigned to BoG

[JVET-L0041](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4122) Non-CE8: Rotate Intra Block Copy [Z. Zhang, V. Sze (MIT)]

This contribution proposes a method called ***rotate intra block copy***, which extends the intra block copy technique by making the block matching process invariant to rotation. HEVC intra prediction plus rotate intra block copy gives an average of 20% reduction in residual energy (i.e., prediction error) compared to HEVC intra prediction plus intra block copy. As the motion vector correlation in rotate intra block copy is different from the intra block copy, a new method of motion vector coding is presented. The impact of angular resolution on residual energy reduction is also evaluated. The reduction in residual energy translates to BD-rate change of -3.4% over HEVC intra prediction plus intra block copy for both screen content and camera-captured gray scale images.

Proponent didn’t attend the BoG, so it was not presented there.

Also no proponent was available Tue 1250 in track A, and the document was investigated.

Seems more as infomative contribution. Interesting to note that usage of rotation in CPR could potentially give additional gain; in particular, as VVC has such elements (affine transform) anyway, however in contrast to current CPR as investigated in the CE, subpixel interpolation would be needed.

[JVET-L0159](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4240) Non-CE8: Block vector predictor for CPR [J. Nam, J. Lim, S. Kim (LGE)]

In merge and AMVP modes, candidate list is first filled from spatial and temporal candidates and zero candidates are then inserted to candidate list until candidate list includes maximum candidates. However, in current picture referencing, block vector for intra block copy cannot become zero. Therefore this contribution proposes, instead of zero candidates, two alternative candidates (-2\*width, 0) and (0, -2\*height) for block vector prediction candidate for intra block copy (IBC) are introduced. Experimental results reportedly show 0.11%, 0.61%, and 1.18% BD-rate savings for CTC, classF, and SCC over VTM-2.0.1 with CPR under AI configuration.

Q: Do you try other position? A: Yes, the proposed is the best position.

Q: Do you consider CPR restriction? A: full range search is performed in the proposal.

It is commented that it might be interesting to have more results of different positions.

It is commented that there was studied during HEVC, the results showed that the best position might not be the nearest one.

The BoG recommended to study in the next CE.

[JVET-L0472](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4576) Cross Check report of JVET-L0159: Non-CE8: Block vector predictor for CPR [X. Xu (Tencent)] [late]

[JVET-L0297](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4392) CE8-related: CPR mode with local search range optimization [X. Xu, X. Li, S. Liu (Tencent), E. Chai (Ubilinx)]

In this contribution, the effective search range for CPR mode with local reference constraints is increased, while it is asserted that the required memory to store reconstructed samples for CPR referencing is kept unchanged. Compared to the constraint with only 1 CTU size of reference area in CE8 test (CE8.3.1b), the proposed method can achieve higher coding efficiency. The reported BD rate changes from the proposed method (reuse the memory buffer on 64x64 basis) relative to VTM-2.0.1 are as follows:

* In AI, -0.27%/-13.61%/-41.31% for CTC/Class F/SCC 1080p classes, separately.
* In RA, -0.14%/-11.13%/-25.50% for CTC/Class F/SCC 1080p classes, separately.
* In LB, 0.02%/-6.07%/-15.71% for CTC/Class F/SCC 1080p classes, separately.

The proposal proposed to reuse the reference sample memory on 64x64 basis. Coding performance improvements of the proposed method are reported on top of VTM-2.0.1 and CE8-3-1b (1CTU, no chroma interpolation).

The availability check of reference samples from left CTU is performed on a 64x64 basis.

Q: why does decoding time decrease? A: time information is not accurate.

It is commented that the search range is irregular from encoder perspective; the starting points of encoding search might different.

It is also commented that the search is the same to the current CE design.

The BoG recommended to study in the next CE.

[JVET-L0518](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4624) Cross check of JVET-L0297 (CE8-related: CPR mode with local search range optimization) [G. Venugopal (HHI)] [late]

[JVET-L0299](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4394) CE8-related: CPR mode with merge mode improvements [X. Xu, X. Li, M. Gao, J. Ye, S. Liu (Tencent)]

In this contribution, the CPR mode is combined with some improvements from merge mode, i.e., non-adjacent and history-based merge candidates (CE4.4.2, CE4.4.7). Combination of the two are tested.

With the improved merge mode CE4.4.2, the reported BD rate changes from the base method (BMS-CPR) are as follows:

* In AI, -0.09%/-0.33%/-1.71% for CTC/Class F/SCC 1080p classes, separately.
* In RA, -0.58%/-0.61%/-2.06% for CTC/Class F/SCC 1080p classes, separately.
* In LB, -0.37%/-0.63%/-1.93% for CTC/Class F/SCC 1080p classes, separately.

With the improved merge mode CE4.4.2, the reported BD rate changes from the base method (CPR with 1 CTU search range, CE8.3.1b) are as follows:

* In AI, -0.06%/-0.21%/-0.95% for CTC/Class F/SCC 1080p classes, separately.
* In RA, -0.57%/-0.56%/-1.69% for CTC/Class F/SCC 1080p classes, separately.
* In LB, -0.43%/-0.50%/-2.12% for CTC/Class F/SCC 1080p classes, separately.

With the improved merge mode CE4.4.2+CE4.4.7, the reported BD rate changes from the base method (BMS-CPR) are as follows:

* In AI, -0.23%/-0.78%/-2.69% for CTC/Class F/SCC 1080p classes, separately.
* In RA, -0.87%/-1.14%/-2.99% for CTC/Class F/SCC 1080p classes, separately.
* In LB, -0.52%/-0.94%/-2.87% for CTC/Class F/SCC 1080p classes, separately.

With the improved merge mode CE4.4.2+CE4.4.7, the reported BD rate changes from the base method (CPR with 1 CTU search range, CE8.3.1b) are as follows:

* In AI, -0.16%/-0.57%/-1.83% for CTC/Class F/SCC 1080p classes, separately.
* In RA, -0.84%/-1.00%/-2.56% for CTC/Class F/SCC 1080p classes, separately.
* In LB, -0.56%/-0.94%/-2.74% for CTC/Class F/SCC 1080p classes, separately.

The proposal provided the information showing that the CPR mode combined the merge mode improvement adopted in this meeting has additional gain.

The proponent suggested that if the CE4.4.7 (adopted merge improvement) is applied to CPR, the addional gain is expected to be similar as the one tested using CE4.4.2 in this contribution.

[JVET-L0626](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4739) Cross-check of JVET-L0299 [H. Jang (??)] [late] [miss]

[JVET-L0404](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4501) CE8-related: Restrictions for the search area of the CPR blocks in CPR [L. Pham Van, V. Seregin, W.-J. Chien, T. Hsieh, M. Karczewicz (Qualcomm)]

This contribution proposes the restrictions to the search area for IBC blocks. The search area is restricted to the current CTU and few CTUs to the left of the current CTU. Additionally, this proposal also proposes to extend the search area to 10 lines above these CTUs. It is reported that with the proposed restricted search area, the Luma BD-rate changes for [CTC, Class F, class SCC 1080p] over BMS2.1-VTM configuration are:

*The current and 1 left CTU without and with extended lines, respectively:*

* AI: (-0.29%, -15.55%, -46.10%) and (-0.32%, -15.79%, -46.99%).
* RA: (-0.10%, -12.67%, -29.42%) and (-0.11%, -12.88%, -30.17%).
* LB: (0.02%, -7.19%, -19.70%) and (-0.32%, -7.38%, -20.18%).

*The current and 2 left CTUs without and with extended lines, respectively:*

* AI: (-0.29%, -15.76%, -46.68%) and (-0.32%, -15.98%, -47.56%).
* RA: (-0.10%, -12.84%, -30.23%) and (-0.11%, -13.06%, -30.99%).
* LB: (0.02%, -7.30%, -20.39%) and (0.02%, -7.62%, -20.96%).

*The current and 3 left CTUs without and with extended lines, respectively:*

* AI: (-0.29, -15.84%, -46.98%) and (-0.32%, -16.06%, -47.85%).
* RA: (-0.10, -12.91%, -30.63%) and (-0.11%, -13.14%, -31.35%).
* LB: (0.02%, -7.52%, -20.94%) and (0.02, -7.67%, -21.52%).

Based on CPR with local search range (current CTU + x left CTUs), this proposal proposes to extend the search area to **N** lines above these CTUs. N is set to be 10 in the proposal, but the proposal also proposed that the number of N should be set accoding to the VVC design. Coding performance using these extra N lines is reported.

It is commented that the reference pixels in N lines are before deblocking stage. It was suggestesd to test N=4 in the next CE.

It is commented that there are different approaches: (1) extend reference to the left CTU (2) top N line.

It is commented that multiple tools can share the same additional required resource.

It is commented that it is better that the required line memory could be in the same memory as the one to store the reference samples in the current and left CTUs.

The BoG recommended to study in the next CE.

Note: During discussion about palette mode, it was suggested that the upcoming CE8 should test CPR technology also in a configuration where the CE15 reference palette mode is enabled.

## CE9 related – Decoder-side motion vector derivation (26)

Contributions in this category were discussed XXday XX Oct XXXX–XXXX (chaired by XXX).

### Decoder motion vector refinement

BoG L0693 results were reviewed 1415-1500 Track B Monday (GJS)

[JVET-L0098](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4179) CE9-related: Simplified DMVR with reduced internal memory [C.-C. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

The method was discussed during the CE9 discussion (see notes above). The decision was to disable the DMVR for the coding block sizes with either width of height of 128. The method was agreed to be included in the CE9 DMVR base software for the next round of CE experimentation.

[JVET-L0653](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4767) Cross-check of JVET-L0098 [X. Chen (HiSilicon)] [late]

In this proposal, two changes related to the cost function used in DMVR are proposed and results related to individual methods and the combined methods are presented. The first aspect relates to restricting the bit-depth of the interpolated samples on which the cost functions are evaluated during DMVR. The second aspect relates to replacing the mean removed sum of absolute differences (MR-SAD) with a refinement position independent MR-SAD (P-I-MR-SAD) cost function. Results reportedly show that the bit-depth restriction has hardly any impact on BD rate with EncT ratio of xxx% and DecT ratio of yyy% compared to the reference method. The P-I-MR-SAD results in a 0.08% BD rate drop when compared to MR-SAD, but offers an EncT ratio of xxx% and DecT ratio of yyy%. The two changes together reportedly result in an EncT ratio of xxx% and DecT ratio of yyy% for DMVR Tool-on over VTM2.

The first aspect proposes to reduce the intermediate bit-depth of prediction samples of the DMVR from 14-bit to 8-bit. Additional buffer size is needed when reducing the internal bit-depth to 8 with a reported 1% decoding time saving.

It is commented the gain on top of UME of the proposed method is approximately 1.3%.

The proponent suggests to study the proposed methods in the CE9.

BoG recommendation: Study in a CE.

[JVET-L0174](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4265) Non-CE9: Simplifications related to cost function in DMVR [S. Sethuraman (Ittiam)]

[JVET-L0532](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4640) Crosscheck of L0174: Non-CE9: Simplifications related to cost function in DMVR [Y.-W. Chen, X. Wang (Kwai Inc.)] [late]

[JVET-L0189](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4280) CE9-related: Improved Unidirectional Template based DMVR [F. Chen, L. Wang (Hikvision)] [late]

This contribution proposes a unidirectional template based DMVR. To avoid latency and reuse the refined MV within a CTU, new candidates based on searching pattern are generated. For bidirectional candidates, a different searching method is proposed. It is reported that the proposed method can provide 2.43%, 0.11%, 0.65% gain for RA, LB, LP respectively compared to VTM-2.0 with around 19% increase in encoding time and 10%~24% increase in decoding time.

One participant mentioned the BD-rate performance in the slides did not match with the results in the contribution document.

BoG recommendation: Study in a CE.

[JVET-L0544](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4652) Crosscheck for L0189 (CE9-related: Improved Unidirectional Template based DMVR) [S. H. Wang, S. S. Wang, S. Ma (Peking University)] [late] [miss]

[JVET-L0314](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4409) CE9-related: Constrained intra prediction with decoder side motion vector derivation [M. Xu, X. Li, S. Liu (Tencent)]

Decoder side motion vector derivation (DMVD) techniques were proposed to derive motion information at decoder side after the parsing stage. As intra prediction may depend on the results of its spatial neighbour’s full reconstruction, it cannot be started until the MV derivation process and the final reconstruction has finished for the previous block, which has a latency impact for hardware pipelines. It is reported that the issue can be resolved with the method proposed in this contribution at the cost of about 0.27% luma BD-rate increase for BMS-2.1-rc1 with VTM configuration and DMVR tool on.

The proponent proposes to disable DMVR inter predicted samples as references for intra prediction.

One participant commented that since this uses intra prediction that uses the results of inter prediction, the proposed method is not helpful for practical hardware design.

The cross-checker commented that the proposed solution could reduce the latency of intra prediction on the DMVR samples.

BoG recommendation: Study in the CE.

[JVET-L0510](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4616) Cross-check of JVET-L0314: CE9-related: Constrained intra prediction with decoder side motion vector derivation [J. Ma (HHI)] [late]

[JVET-L0367](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4464) CE9-related: An early termination of DMVR [T. Chujoh, T. Ikai (Sharp)]

DMVR (decoder motion vector refinement) is a method of improving coding efficiency without explicitly sending overhead by motion vectors refinement of the merge mode. One of the tasks is to reduce the complexity of the decoder side. In this contribution, an early termination of DMVR is improved. As experimental results, the decoding time was reportedly reduced by about 2% without additional SIMD usage, and the coding efficiency was reportedly almost unchanged. It is also possible to introduce it to integrated CE methods additionally.

Difference compared to the CE9:

|  |  |  |  |
| --- | --- | --- | --- |
| Method | Error criterion | Threshold | Applied position |
| CE9.2.7 (JVET-L0197) | SAD | BitDepth-9 | Before DMVR process |
| Our proposal (JVET-L0367) | MRSAD | BItDepth-8 | Fix of initial DMVR process |

One participant suggested to replace the SAD with MRSAD with a larger threshold (2X) when calculating the initial MRSAD at the center point.

BoG recommendation: Study in the CE.

[JVET-L0538](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4646) Crosscheck of L0367: CE9-related: An early termination of DMVR [S. Esenlik (Huawei)] [late]

[JVET-L0619](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4732) Crosscheck report of JVET-L0367 (CE9-related: An early termination of DMVR) [J. Luo (InterDigital)] [late]

[JVET-L0382](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4479) CE9-related: DMVR with Coarse-to-Fine Search and Block Size Limit [K. Unno, K. Kawamura, S. Naito (KDDI)]

This contribution presents a proposal of search method for bilateral DMVR. In the proposed method, 10 points, including half pel positions, are searched by 3 stages when search range is 2. Furthermore, disallowing DMVR at large CUs is proposed in this contribution. BD-rate gains for luma is -1.07% under the RA conditions in case of comparing with BMS2.1 rc1 with VTM configuration.

The first method reduces the worst-case of the search points from 13 to 10 with the BD-rate performance of 0.43%. Since this is a substantial loss, the BoG did not recommend including this in a CE study.

The second aspect of disabling the DMVR for the CU sizes with either width or height of 128 had already been included in the CE9 DMVR base software.

[JVET-L0598](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4711) Cross-check of JVET-L0382: CE9-related: DMVR with Coarse-to-Fine Search and Block Size Limit [H. Gao (Huawei)] [late]

[JVET-L0670](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4784) Simplified DMVR for inclusion in VVC [S. Esenlik, A. M. Kotra, B. Wang, H. Gao, J. Chen (Huawei), S. Sethuraman (Ittiam)] [late]

This contribution document reports the result of the combination of CE9 tests to reduce the complexity of DMVR in BMS2.1. It is asserted that the proposed DMVR is algorithm provides significant reduction in complexity while increasing the coding gain. Reported gain of 1.67% in luma BD-rate, with Cb and Cr 1.68% and 1.80% chroma BD-rate gain is reported with 1% increase in encoding time and 6% increase in decoding time compared to the BMS anchor with VTM encoder configuration.

The contribution reports the combination of following CE tests:

* Reference sample padding for eliminating memory BW increase (CE9.2.2)
* Integer based DMVR to eliminate intermediate interpolation filters and buffers (CE9.2.1)
* Use refined MV from top and top-left CU (CE9.1.4)
* Parametric error surface based sub-pel refinement (CE9.2.5)
* Disable DMVR for small blocks and subsampled MRSAD (CE9.2.9f)
* Early-termination based on MV difference between merge candidates(CE9.2.13a)

The proposed modifications are independently tested in CE9.

The proponent proposes to adopt the contribution to VVC.

In the previous CE, the main concerns are internal buffer size. CE9.2.1 solves the problem of the internal buffer problem.

It is commented the performance is interesting; but, due to the adoptions at the current meeting, there might be interactions of the method with the new adoptions (e.g., because this has a symmetric motion assumption that is also used in another technique adopted at the meeting - MMVD).

The maximal CU size is 128x128.

The proponent mentioned that if not using MRSAD the loss is 0.24%.

BoG recommendation: Study in the CE.

In Track B review of the BoG report, the proponent said they had tested the scheme in combination with an MMVD method similar to what was adopted (disabling DMVR for blocks that use MMVD and disabling DMVR for blocks Nx8/8xN/Nx4/4xN blocks), and found a BD rate gain of DMVR 1.1% for RA.

Another participant said they estimated gain as 0.9% and commented that since the proposal was late, they could not check it more thoroughly.

A participant said that since this is applied to large blocks, it would add a requirement of large amount of cache memory capacity (~128k), and suggested considering limiting the scheme to smaller blocks (or forcing a split to smaller blocks) than the proposed size range of up to 128x128.

A different variant of DMVR had been tested with a forced split of this sort (splitting to 32x32) as reported in L0098, with a small impact on coding efficiency (about 0.07% loss). It was commented that such a split might cause artefacts, since the transform spans the block boundaries.

It was remarked that there are multiple possible approaches to the large block issue that can be studied.

It was agreed to further study this scheme in a CE.

[JVET-L0671](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4785) Crosscheck of JVET-L0670 (Simplified DMVR for inclusion in VVC) [T. Chujoh (Sharp)] [late]

The cross-checker remarked that the software codebase used to test the scheme was based on CE9 software with some simplifications.

### Bidirectional optical flow

[JVET-L0061](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4142) CE9-related: Bi-directional optical flow for VTM [K. Choi, M. W. Park, A. Tamse, K. P. Choi (Samsung)]

This was discussed Saturday 2000 (GJS).

This contribution describes Bi-directional optical flow (BIO) which is used in BMS2.0. In JVET 11th meeting, a simplification of BIO considering an early termination based on the similarity between two bi-prediction signals was adopted for BMS2.1. In this contribution, testing results of BIO in BMS2.1 is provided. For VTM test in RA case, BIO in BMS2.1 shows 1.4% coding gain on average for luma with 104% encoding time and 120% decoding time compared to BMS2.1 with VTM configuration.

The performance of BIO was reported in the contribution. It was suggested to focus on other contributions in this area. The information is available for study.

[JVET-L0256](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4351) CE9-related: Complexity reduction and bit-width control for bi-directional optical flow (BIO) [X. Xiu, Y. He, Y. Ye (InterDigital)]

This was discussed Saturday 2105 (GJS).

Bi-directional optical flow (BIO) is include in benchmark set (BMS)-2.1. The current BIO implementation in the BMS-2.1 requires 33-bit multiplier and has the maximal bit-width of 43 bits for intermediate parameters. When BIO is enabled, the number of multiplications is reportedly 329% of the worst-case number of multiplications for regular bi-prediction for 4x4 blocks, representing a significant increase in worst-case computation complexity.

In this contribution, two methods are proposed to address the BIO’s complexity issues.

* A bit-width control method is proposed to ensure BIO can be implemented with at most a 15-bit multiplier and the intermediate values are within the 32-bit range.
* A method is proposed to lower the BIO’s computational complexity by using bilinear filters to interpolate prediction samples and reducing the area of extended region for BIO derivation. Further, BIO is disabled if either of the following is true: 1) the CU has height equal to 4 or the CUs is in size of 4×8, or 2) the CU is coded with sub-block modes.

The worst-case number of multiplications involved in the BIO can reportedly be reduced to 103% of that of regular bi-prediction by the proposed changes.

Experimental results reportedly show that compared to the VTM-2.1, the combination of the proposed changes provides average {Y, U, V} BD-rate savings of {1.28%, 0.52% and 0.37%} with encoding and decoding time of 102% and 102%, respectively. The existing BIO implementation in the BMS-2.1 reportedly provides an average {Y, U, V} BD-rate saving of {1.41%, 0.58%, 0.40%} with encoding and decoding time of 103% and 113%, respectively. Based on the simulation results, it is asserted that with the proposed methods, BIO becomes an implementable tool with a desirable performance vs. complexity trade-off.

Text was not provided, but was being prepared.

It was reported that the existing design cannot be implemented readily with SIMD operations on typical processors due to bit width concerns. The results reported for the proposed method used some SIMD operations. There was discussion of whether the SIMD usage was appropriate, and it was said that the other inter prediction processes in the software have used SIMD implementation as well.

Similar approaches to complexity reduction had been suggested in different proposals that had been developed independently.

A participant commented that a number of aspects of this are new and should be studied.

It was also commented that there may be overlap in gain between BIO and DMVR. Others said that the gains do not substantially interfere with each other.

BIO has been in the BMS previously and has been studied in some form for years. This drop the complexity of the proposal very substantially.

Decision: Adopt (subject to text review).

Further study of additional refinements was encouraged.

[JVET-L0591](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4703) CE9-related: A simplified design of bi-directional optical flow (BIO) [X. Xiu, Y. He, Y. Ye (InterDigital), C.-Y. Lai, Y.-C. Su, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)] [late]

This was discussed Saturday 2020 (GJS).

In this contribution, methods are proposed to make the existing design of bi-directional optical flow (BIO) tool in BMS-2.1 more implementation friendly. To control the size of the multipliers in BIO, one bit-width control method is applied to ensure BIO can be implemented with at most 15-bit multiplier and the intermediate values are within the 32-bit range. Further, three solutions are provided to reduce the BIO worst-case computational complexity by reducing or avoiding the interpolation of the prediction samples in the extended area of one BIO CU. Additionally, in all three solutions, the BIO is disabled if either of the following is true: 1) the CU has height equal to 4 or the CUs is in size of 4×8, or 2) the CU is coded with sub-block modes. Compared to VTM-2.1 anchor, the performances of the proposed BIO simplifications are summarized as follows:

The existing BIO in the BMS-2.1:

{Y, U, V} BD-rate saving {1.41%, 0.58%, 0.40%}, EncT=103%, DecT=119%

The bit-width control method + complexity reduction solution one:

{Y, U, V} BD-rate saving {1.29%, 0.53%, 0.35%}, EncT=100%, DecT=105%

The bit-width control method + complexity reduction solution two:

{Y, U, V} BD-rate saving {1.24%, 0.48%, 0.37%}, EncT=100%, DecT=102%

The bit-width control method + complexity reduction solution three:

{Y, U, V} BD-rate saving {1.17%, 0.47%, 0.32%}, EncT=101%, DecT=103%

Based on the simulation results, it is asserted that with the proposed simplification methods, BIO becomes an implementable tool with desirable performance vs. complexity trade-off.

This was described as being mostly similar to L0256. The contributor said this could be studied later in a CE while adopting L0256.

[JVET-L0660](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4774) Crosscheck of L0591: CE9-related: A simplified design of bi-directional optical flow (BIO) [Y.-W. Chen, X. Wang (Kwai Inc.)] [late]

[JVET-L0669](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4783) Cross-check of JVET-L0591 (CE9-related: A simplified design of bi-directional optical flow (BIO)) [T. Poirier, F. Le Léannec (Technicolor)] [late]

[JVET-L0099](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4180) CE9-related: BIO simplifications [C.-Y. Lai, Y.-C. Su, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

The contributor said this contribution did not need separate presentation from L0591.

[JVET-L0562](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4672) Crosscheck of JVET-L0099 (CE9-related: BIO simplifications) [T.-H. Li, Y.-C. Yang, Y.-J. Chang (Foxconn)] [late]

[JVET-L0123](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4204) CE9-related: Simplification of BIO [J. Li, C. S. Lim (Panasonic)]

2055

[add abstract]. Study in a CE is planned

[JVET-L0586](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4697) Crosscheck of JVET-L0123 (CE9-related: Simplification of BIO) [C.-Y. Lai (MediaTek)] [late]

[JVET-L0333](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4429) CE9-related: Motion Vector Refinement in Bi-directional Optical Flow [H. Liu, L. Zhang, K. Zhang, Y. Wang, P. Zhao, D. Hong (Bytedance)]

2055

[add abstract]. Study in a CE is planned.

Some concern was expressed about hardware pipeline issues.

[JVET-L0511](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4617) Cross-check result for JVET-L0333 [Y. Piao, K. Choi, K. P. Choi (Samsung)] [late]

## CE10 related – Combined and multi-hypothesis prediction (2)

Contributions in this category were discussed XXday XX Oct XXXX–XXXX (chaired by XXX).

[JVET-L0208](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4299) CE10 related: multiple prediction unit shapes [T. Poirier, F. Le Léannec, P. Bordes (Technicolor)]

This contribution was discussed Saturday 1800 (GJS).

This contribution provides test results of multiple prediction unit shapes, this test is built on top of CE10.3.1.b. A CU can be split using 2 prediction units, in either diagonal or inverse diagonal direction or horizontal or vertical direction with multiple positions. Each prediction unit in the CU has its own uni-prediction motion vector and reference frame index which are derived from a uni-prediction candidate list. Multiple shapes partitioning is only applied to motion compensated prediction, which means that the transform and quantization process is applied to the whole CU formed by combining the two prediction units together. In this contribution, the triangular prediction unit mode is only applied to a CU which block size is larger than or equal to 8×8, and its coding prediction mode is either skip or merge mode. It is reported that as compared to VTM-2.0.1, 0.78% B-D rate saving with 158% encoding time and 105% decoding time is achieved in random access configuration. 1.57% B-D rate saving with 164% encoding time and 94% decoding time is achieved in low delay B configuration.

There are two elements to the proposal:

* A “bug fix” for the blending process
* Additional prediction segmentation shapes

The encoder complexity, as tested, is high, but the proponent indicated that this could be improved with further work.

The “bug fix” aspect was agreed to be an improvement relative to the proposed triangle method. Further study would be needed to evaluate the value of the addition segmentation shapes. CE study is planned.

[JVET-L0571](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4681) Crosscheck of JVET-L0208: CE10 related: multiple prediction unit shapes [R.-L. Liao, C. S. Lim (Panasonic)] [late]

[JVET-L0375](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4472) CE4-related: Inter prediction sample filtering [W. Xu, H. Yang, Y. Zhao, J. Chen (Huawei)]

This contribution was discussed Saturday 1830 (GJS).

This had been submitted as CE4 related but seemed more CE10 related.

This contribution reports the results of inter prediction samples filtering. A spatial filter is applied on the prediction samples from merge/skip mode. A CU-level flag is added to indicate whether using inter prediction samples filtering. Compared to the VTM2.0.1 anchor, the average BD-rate is -0.29%~-0.48% in RA with different filter.

Further study in a CE was suggested.

[JVET-L0679](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4793) CE10-related: Multi-Hypothesis Inter Prediction with simplified AMVP process [M. Winken, H. Schwarz, D. Marpe, T. Wiegand (HHI)] [late]

See notes in CE 10 summary section JVET-L0030.

## CE11 related – Deblocking (13)

Contributions in this category were discussed reviewed in BoG L0681. (add text from BoG report).

[JVET-L0226](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4317) CE11- related: Position dependent adaptive Tc clipping range for deblocking filter [A.M. Kotra, S. Esenlik, B. Wang, H. Gao, Z. Zhao, J. Chen (Huawei)]

[JVET-L0621](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4734) Cross-check of JVET-L0226 (CE11-related: position dependent adaptive Tc clipping range for deblocking filter) [P. Onno, G. Laroche (Canon)] [late]

[JVET-L0393](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4490) CE11-related: Improvement of Extended Deblocking Filter [K. Unno, K. Kawamura, S. Naito (KDDI)]

[JVET-L0566](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4676) Crosscheck for JVET-L0393 (CE11-related: Improvement of Extended Deblocking Filter) [W. Choi, K. Choi (Samsung)] [late]

[JVET-L0410](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4508) CE11-related: On deblocking tC table [A. Norkin (Netflix)]

Decision: Adopt JVET-L0410, updated tC table into VVC text & VTM (track A Wed 10 Oct., 1200, chaired by JRO)

[JVET-L0460](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4564) CE11.1.11 related: Improvements to smoothness decision for long luma filters [K. Andersson, Z. Zhang, R. Sjöberg, W. Zhu (Ericsson), K. Misra, P. Cowan, A. Segall (Sharp Corporation)] [late]

[JVET-L0523](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4629) CE11-related: Very strong deblocking filtering with conditional activation signalling [C. Helmrich (HHI)] [late]

[JVET-L0529](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4635) CE11.1.10-related: Smoothness threshold modification for long tap deblocking [W. Zhu, K. Misra, A. Segall (Sharp), M. Ikeda, T. Suzuki (Sony)] [late]

[JVET-L0558](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4668) CE2/CE11-related: Deblocking TC offset for VTM [N. Hu, V. Seregin, M. Karczewicz (Qualcomm)] [late]

[JVET-L0572](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4682) CE11-related: CTU line buffer reduction for long filter deblocking [A.M. Kotra, S. Esenlik, B. Wang, J. Chen (Huawei), W. Zhu, K. Misra, P. Cowan, A. Segall (Sharp)] [late]

[JVET-L0661](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4775) Crosscheck of JVET-L0572 (CE11-related: CTU line buffer reduction for long filter deblocking) [M. Ikeda (Sony)] [late]

[JVET-L0614](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4727) CE11-related: Additional tests of CE 11.3.3 and 11.3.4 for 4 x N and N x 4 deblocking [A.M. Kotra, S. Esenlik, B. Wang, H. Gao, Z. Zhao, J. Chen (Huawei), Chia-Ming Tsai, Chih-Wei Hsu, Tzu-Der Chuang, Ching-Yeh Chen, Yu-Wen Huang, Shaw-Min Lei (MediaTek)] [late]

[JVET-L0645](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4758) Cross-check of JVET-L0614 (CE11-related: Additional tests of CE 11.3.3 and 11.3.4 for 4 x N and N x 4 deblocking) [J. Dong (Qualcomm)] [late]

## CE12 related – Mapping functions (3)

Contributions in this category were discussed XXday XX Oct XXXX–XXXX (chaired by XXX).

[JVET-L0247](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4339) CE12-related: Universal low complexity reshaper for SDR and HDR video [T. Lu, S. McCarthy, F.n Pu, P. Yin, W. Husak, T. Chen (Dolby)]

In-loop reshaping was tested in CE-12 mapping functions for both SDR and HDR video.

This contribution recommends a universal low complexity in-loop reshaping architecture for both SDR and HDR. The proposed universal reshaper has the key advantage that it provides significant performance gains with minimal impact on implementation. As such, it provides the best balance between complexity and improved compression efficiency for both SDR and HDR.

Specifically, the proposed reshaper benefits by performing source mapping for both intra and inter slices at the same location in the decoder workflow. The proposed reshaper also benefits by applying loop filtering in the original (non-mapped) domain for which loop filters were originally designed and optimized. In addition, the proposed reshaper enables slice level adaption needed to optimize coding efficiency at the picture level.

The proposed reshaper has two main components: 1) in-loop reshaping applied to the luma component; 2) complementary chroma residue scaling applied to chroma components

The proposed universal reshaper has the following performance gains:

* For SDR video, average BDRate for Y/U/V:
  + RA {-1.32%, 2.07%, 1.62%}
  + AI { -0.96%, 2.56%, 2.13%};
* For HDR video, average BDRate for wPSNRY/PSNR100/DE100:
  + RA {-1.8%, -2.0%, 2.3%}
  + AI { -1.7%, -2.0%, 1.4%}

Performance gains are larger for higher resolution video (UHD and HD):

* For SDR video, average BDRate for Y/U/V:
  + RA {-1.43%, 2.18%, 1.47%}
  + AI { -1.36%, 2.51%, 1.84%}

The decoding running time increase is 5% or less. The encoding running time increase is 7% or less.

It is recommended that the proposed universal reshaper be adopted as a core coding tool in VVC for SDR and HDR.

Unification of in-loop reshaping for SDR and HDR cases, both in “low complexity” configuration with 10 bit LUT implementing piecewise linear function. Coding of prediction residual is always done in reshaped domain (regardless if it is intra or inter). For intra slices, it is not necessary to perform the steps of inverse reshaping after block reconstruction, because the loop filter is anyway kind of post processing.

Improved figures for understanding the method are in v2 of the doc.

Further investigation in CE12 (see further notes there).

[JVET-L0490](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4595) CE12-related: HDR Coding with Backward Compatibility Options [P. Topiwala, M. Krishnan, W. Dai (FastVDO)] [late]

This smbmission presents an approach to HDR/WCG video coding developed at FastVDO, which we call FVHDR, and built on top of the Versatile Video Coding (VVC) VTM2.0.1 test model of the Joint Video Exploration Team. A fully automatic adaptive video process that differs from a known HDR video processing chain (analogous to HDR10, and herein called “anchor”) developed previously in the JCT-VC, is used. FVHDR works entirely within the framework of the VTM software model, but adds additional tools. These tools can become an integral part of a future VVC video coding standard, or be developed as additional pre- and post-processing chains (as an example, presented as pre/post processes in this proposal). Reconstructed videos codec with the proposed system are claimed to show subjective improvement over the anchor system. Moreover, the resultant SDR content generated by the proposed data adaptive grading process is claimed to offer backward compatibility options, which can be developed in follow-on work.

Presented by non-proponent track A Wed. 10 afternoon.

The current implementation is implemented as out-of-loop reshaping, but it could also be done in-loop. Reshaping function is piecewise-linear, automatically adapted (could be on a frame by frame basis, but exact procedure not known). Cross checkers reported that the results, but the implementation is not based on the recommended VTM2 configuration.

Visual investigation was not done.

Noted for information, no action.

[JVET-L0622](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4735) CE12-related: cross-check report of JVET-L0490 on HDR Coding in VVC with Backward Compatibility Option [C. Chevance (Technicolor)] [late]

## CE13 related – Coding tools for 360° omnidirectional video (4)

Contributions in this category were discussed XXday XX Oct XXXX–XXXX (chaired by XXX).

[JVET-L0166](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4257) CE13-related: Subjective Quality Improvement for RSP [A. Singh (Samsung)] [late]

[JVET-L0212](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4303) CE13-related: Results for experiments as CE13.3.2, CE13.4.3 and CE13.7.7 with PHEC and impact of rotation on the coding performance of PHEC [J. Sauer, M. Bläser (RWTH Aachen University)]

[JVET-L0237](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4328) CE13-related: Adaptive frame packing using chroma sample location type 1 [P. Hanhart, Y. He, Y. Ye (InterDigital)]

[JVET-L0423](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4522) CE13-related: HEC with in-loop filters using spherical neighbours [Xuchang Huangfu, Yule Sun, Lu Yu (Zhejiang Univ.) [late]

[JVET-L0238](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4329) AHG8: Chroma sample location type support for 360Lib [P. Hanhart, Y. He, Y. Ye (InterDigital)]

This was discussed in the 360° video BoG, and related notes are elsewhere in this report.

[JVET-L0698](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4812) Cross Check report of JVET-L0238: AHG8: Chroma sample location type support for 360Lib [A. Singh, C. Pujara, A. Konda (Samsung)] [late]

## CE14 related – Post-reconstruction filtering (7)

Contributions in this category were discussed Wednesday 10 Oct 1700–1740 (chaired by JRO).

Assigned to BoG

[JVET-L0357](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4454) CE14 related: Adaptive colour space clipping filter [T. Chujoh, T. Ikai (Sharp)]

(not reviewed in BoG)

In the video coding, the samples on the YCbCr space that are transformed from the RGB space by a standard such as ITU-R BT.709 are coded. Since not all samples of the three-dimensional YCbCr space are included into original RGB space, there are some possibilities that samples outside original RGB space can be generated by coding loss. In this contribution, a loop filter called an adaptive colour space clipping filter that corrects the samples outside the colour space has been proposed. It was implemented on BMS-2.01 software, and two methods that are clipping of all YCbCr values and only CbCr values have been tested with VTM configuration. As experimental results, on the RA condition, the average gain of all YCbCr clipping were -0.20%/-0.95%/-1.50% for Y/Cb/Cr respectively and the average encoding and decoding times were 100%/110%. The average gain of clipping of only CbCr are -1.07%/-1.57% for Cb/Cr respectively, the average encoding and decoding times were 100%/104%. There were high Chroma gains up to 11% with several specific sequences with highlight and shadow, FoodMarket4, Campfire (Class A1), ShowGirl2 and Cosmos1 (HDR-B).

Clipping is applied after all in-loop filters.

The gain is relatively small (and specific for some sequences). This could be due to the fact that pixels exist which are very close to the specified limits of the respective clour space, and du to compression artifacts, they are exceeding the range.

It is also pointed out that some sequences are out of legal range (class F sequences BasketballDrillText, SlideEditing, SlideShow), where the adaptivity at slice level is especially effective.

Very likely that similar gain could be achieved by out-of-loop (post-)processing.

The JEM tool for picture adaptive luma clipping targets a similar issue, likely even has more gain, but is not in VVC.

Further study is encouraged.

[JVET-L0583](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4694) Crosscheck of JVET-L0357 (CE14 related: Adaptive colour space clipping filter) [S. Iwamura (NHK)] [late]

[JVET-L0465](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4569) Cross-check of JVET\_L0357 - CE14 related: Adaptive colour space clipping filter [P. Bordes (Technicolor)] [late]

[JVET-L0049](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4130) AHG16: An architecture study of bilateral filters [Y. Hu, M. Zhou (Broadcom)]

To be discussed in BoG (JVET-L0684)

[JVET-L0584](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4695) CE14.2-related: Extended applicability of bilateral filter (CE14.2.c) [D. Rusanovskyy, N. Shlyakhov, M. Karczewicz (Qualcomm)] [late]

To be discussed in BoG (L. Zhang)

[JVET-L0615](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4728) CE14-related: Inter-only bilateral filtering [J. Ström, P. Wennersten, J. Enhorn, D. Liu, K. Andersson, R. Sjöberg] [late]

To be discussed in BoG (JVET-L0684)

[JVET-L0656](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4770) CE14.3-related: Hadamard transform domain filter with modified LUT [S. Ikonin, V. Stepin, D. Kuryshev, A. Karabutov, J. Chen (Huawei)] [late]

To be discussed in BoG (JVET-L0684)

[JVET-L0677](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4791) CE14 related: Decoder run time analysis non-SIMD and SIMD [J. Ström, P. Wennersten, J. Enhorn, D. Liu, K. Andersson, R. Sjöberg (Ericsson)] [late]

To be discussed in BoG (JVET-L0684)

## CE15 related – Palette mode (11)

Contributions in this category were discussed XXday XX Oct XXXX–XXXX (chaired by XXX).

Assigned to BoG

[JVET-L0213](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4304) CE15-related: Combination of palette mode and intra prediction [Y.-C. Sun, J. An, J. Lou (Alibaba)]

This document proposes a method combining palette mode and intra prediction. On top of CE15.1, for Class F sequences, in AI/RA/LDB configuration, the results show -0.2%/-0.2%/-0.1% BD-rate luma gain; for 4:2:0 TGM sequences in CE15, the results show -0.7%/-0.4%/-0.1% BD-rate luma gain.

In current palette mode, the block is entirely predicted without any other prediction method. The contribution proposes to combine the predictors from palette mode and intra prediction mode.

* For a decoded index being zero, the pixel is predicted from intra prediction; intra prediction mode needs to be signaled.
* For an index being non-zero, the pixel is predicted using a palette colour.
* No residue processing is proposed.

Some gain observed for SCC content. The CE15.1 is the base palette software to apply the proposed method.

It was asked if the results are based on CPR mode enabled. It was answered that CPR mode is not used in the reported test.

It is commented that intra 4x4 is the critical path. For the decoding of the combined mode, palette decoding also needs to finish processing within the same number of the cycles for intra 4x4.

It is noticed that some runtime increase is observed.

It is commented that all CE tests should be based on the same base software.

The BoG recommended to study in the next CE.

[JVET-L0574](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4684) Crosscheck of JVET-L0213 (CE15-related: Combination of palette mode and intra prediction) [C.-M. Tsai (MediaTek)] [late]

[JVET-L0307](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4402) CE15-related: Palette index map scan order constraints [J. Ye, X. Li, S. Liu, X. Xu (Tencent)]

In this contribution, the constraints on palette mode index map scan order are proposed. In VTM 2.0.1, there are non-square coding blocks. Some coding blocks have large height/width or width/height ratios. For these blocks, it is proposed to use one scan order. The proposed method reports negligible loss compared to CE15.2 and reduced complexity.

Q: is it separated palette? A: separated for intra/inter slices.

Q: is other shape restriction tried? A: if the threshold is reduced, loss is observed.

It is commented that decoder depends on CU size.

It is also commented that the information is already ready, the impact on parsing dependency is not critical.

The BoG recommended to study in the next CE.

[JVET-L0556](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4666) Crosscheck of JVET-L0307 on CE15-related: Palette index map scan order constraints [J. Nam (LGE)] [late]

[JVET-L0308](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4403) CE15-related: Palette mode when dual-tree is enabled [J. Ye, X. Li, S. Liu, X. Xu (Tencent)]

In this contribution, the modification on palette mode when dual tree is enabled is proposed. In VTM 2.0.1, for I slice, the dual tree is enabled, and luma CTU and chroma CTU have different tree structure. In the HEVC SCC palette mode, the luma sample and chroma sample are interleaved coded. In this case, the HEVC SCC palette mode cannot directly be applied on VTM 2.0.1. In this contribution, two methods are proposed to solve this issue. The proposed method 1 reports -11.64%, -7.75%, -7.55% luma and chroma BD rate changing for AI configuration on class F over VTM 2.0.1. And reports -9.00%, -7.07%, -7.14% luma and chroma BD rate changing for RA configuration on class F over VTM 2.0.1. The proposed method 2 reports -11.60%, -8.56%, -8.35% luma and chroma BD rate changing for AI configuration on class F over VTM 2.0.1. And reports -8.88%, -7.75%, -8.12% luma and chroma BD rate changing for RA configuration on class F over VTM 2.0.1.

Two methods are proposed for palette mode when dual tree is enabled:

Method 1: only apply palette mode to luma plane when dual tree is enabled. In this case, only one palette table and one index map for luma CU will be signaled. When coding chroma plane separately, palette mode will not be used. The other available modes, such as intra chroma mode coding, will be used.

Method 2: apply palette mode to luma plane when dual tree is enabled. When coding chroma plane, if the co-located luma blocks are all coded in palette mode, the chroma block are also have the flexibility to use palette mode. A flag is signaled whether the chroma block using palette mode or not. If the chroma block using palette mode, the corresponding palette mode syntax will be signaled.

It is reported that some loss is observed in Method 1, and the loss is less in Method 2.

In Method 2, there is no syntax for the chroma CU if any of collocated luma CU is not coded in palette mode.

It is commented that the chroma CU could be set to palette mode without syntax if the collocated luma CUs are coded by the palette mode.

The BoG recommended to study in the next CE.

[JVET-L0526](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4632) Crosscheck report of L0308 (CE15-related: Palette mode when dual-tree is enabled) [B. Choi (Sharp)] [late]

[JVET-L0427](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4526) CE15-related: Separate Palette Coding for Luma and Chroma Components [R. Chernyak, S. Ikonin, J. Chen (Huawei)]

The contribution proposes a unification of Palette Coding tool for Single and Dual Trees. For screen content sequences it demonstrates 9.0% / 3.9% / 1.3% (AI / RA / LDB) on class TGM and 4.0% / 3.3% / 2.4% (AI / RA / LDB) on class F of Luma BD-rate saving on top of CE15.2, if Dual Tree is disabled.

In the current CTC, the palette is separated when the dual tree is enabled in SPS. The proposal proposed to use separate palette when the dual tree is disabled in SPS.

It is reported that coding performance benefit can be observed in non-CTC case by enabling separate palette for luma/chroma as compared to joint palette.

It is commented that joint palette requires sending one set of palette information, while separate palettes for luma/chroma maintain two sets of palette information. There is an increase of the complexity.

It is questioned by an expert that for CTC setting, if joint or separate palette should be used. It was requested that both should be evaluated.

This was further discussed in Track A. This should be included in the CE.

Non-CTC case (disabling separate tree) should also be investigated, as it allows using HEVC (joint) palette as is (joint palette). This would likely cause some loss compared to the anchor (which is CE15.2)

Tests:

ST disabled + joint palette (inter+intra)

ST enabled + separate palette (in intra slice) – anchor=CE15.2

ST enabled + separate palette (inter+intra) = L0672

ST disabled + separate palette (inter+intra) = L0427

[JVET-L0612](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4725) Crosscheck of JVET-L0427: CE-15 related: Separate Palette Coding for Luma and Chroma Components [S. Bandyopadhyay (InterDigital)] [late]

[JVET-L0451](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4551) CE15-related: Palette predictor list enhancement [J. Ye, X. Li, X. Xu, S. Liu (Tencent)] [late]

In this contribution, it is proposed to derive the spatial palette predictor from the spatial neighbouring blocks’ palette table first. Then combine the spatial palette predictor with HEVC SCC palette predictor. The proposed method reports -0.14%, -0.04%, and -0.04% luma and chroma BD rate changing for AI configuration on class SCC over CE 15.2.

Q: does the proposal consider CTU boundary? A: Yes.

The crosschecker commented that it is interesting to investigate the correlation between the current palette and non-adjectent palette. It is good to study this method in the CE.

The BoG recommended to study in the next CE.

[JVET-L0550](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4659) Crosscheck of JVET-L0451 (CE15-related: Palette predictor list enhancement) [Y.-C. Sun (Alibaba)] [late]

[JVET-L0672](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4786) CE15-related: Separated palette test on top of CE15.2 [Y.-H. Chao, H. Wang, V. Seregin, M. Karczewicz (Qualcomm), Y.-C. Sun, J. An, J. Lou (Alibaba)] [late]

This document reports the results of joint and separated palettes for luma and chroma CUs in inter slice when dual tree is enabled in SPS. The test is performed on top of CE15.2 (L0336). The results show that:

1. For joint palette, 8.6%, and 4.3% BD-rate gains for luma are shown for class F sequences and 15.6%, and 6.5% BD-rate gains for luma are shown for 4:2:0 TGM sequences under RA, and LD configurations, respectively.

For separated palettes, 8.7%, and 5.2% BD-rate gains for luma are shown for class F sequences and 16.4%, and 8.6% BD-rate gains for luma are shown for 4:2:0 TGM sequences under RA, and LD configurations, respectively.

The proposal showed the information that the separated palettes shows about 1% gain than the joint palette.

[Check notes merge d8\_j1 re “Study in CE (see notes under L0427)”]

Study in CE (see notes under L0427)

## NN technology related (3)

Contributions in this category were discussed Wednesday 10 Oct 1740–XXXX (chaired by JRO).

[JVET-L0242](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4334) AHG9: Dense Residual Convolutional Neural Network based In-Loop Filter [Y. Wang, Z. Chen, Y. Li (Wuhan Univ.), L. Zhao, S. Liu, X. Li (Tencent)]

This contribution presents the simulation results of dense residual convolutional network based in-loop filter (DRNLF), which was proposed in JVET-K0391. Multiple modifications have been carried out to simplify the network in terms of network structure, training materials, and training process. With the proposed modifications, the number of the network parameters have been reduced from 810K to 22K. Simulation results report 2.34%, 1.61%, 2.14% BD-rate savings for Y, Cb, and Cr components compared with VTM2.0.1 under AI configuration.

Decoding time 61x in AI (CPU implementation), reduced from 800x in previous contribution. However, the gain was also larger, 5.7% luma, approx. 15% for AI.

Partial results are reported for RA Class C 2.4% luma gain (AI 3.1%), class D 3% (AI 3.7%)

[JVET-L0546](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4655) Crosscheck of JVET-L0242: AHG9: Dense Residual Convolutional Neural Network based In-Loop Filter [X. Song, L. Wang (Hikvision)] [late]

[JVET-L0383](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4480) AHG9: Convolution Neural Network Filter [K. Kawamura, Y. Kidani, S. Naito (KDDI)]

This contribution presents the results where Convolution Neural Network Filter (CNNF) proposed in JVET-J0016 is implemented on the top of VTM-2.0.1 and used as in-loop filter instead of the current multiple filter such as deblocking filter (DBF), sample adaptive offset (SAO) and adaptive loop filter (ALF). The simulation results show the BD-rate for luma is -0.93% for AI where CNNF is replaced by DBF, SAO and ALF though the BD-rate is -2.21% for AI where CNNF is replaced by DBF and SAO only.

Decoding time (CPU) approx. 2000x.

BoG (S. Liu) to suggest action such as investigating the methods with different configurations to get better understanding about complexity/performance tradeoffs. See the notes for the BoG report L0704.

## Screen content tools (2)

Contributions in this category were discussed XXday XX Oct XXXX–XXXX (chaired by XXX).

Assigned to BoG

[JVET-L0078](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4159) AHG11: Block DPCM for Screen Content Coding [M. Abdoli, G. Clare, F. Henry, P. Philippe (Orange)]

This contribution proposes to use DPCM at the block level to encode Screen Content. The proposed Block-DPCM uses the MED predictor of the JPEG-LS (LOCO-I) algorithm. The prediction error is quantized in the spatial domain and encoded using unary binarization of amplitude and bypass coding of signs. This contribution reports the following compression performance changes for the different tested categories (a negative value indicating an overall gain for Block-DPCM):

Class A to E, All Intra: -0.1% (EncT 103%, DecT 99%)

Class F, All Intra: -7.0% (EncT 103%, DecT 89%)

TGM, All Intra: -21.0% (EncT 105%, DecT 73%)

Class A to E, Random Access: 0.0% (EncT 100%, DecT 100%)

Class F, Random Access: -5.1% (EncT 102%, DecT 96%)

TGM, Random Access: -9.8% (EncT 102%, DecT 92%)

The methods were also tested when combining CE8 CPR and CE15 palette mode, separately.

On top of BMS-CPR, additional 1.1% gain is reported; On top of palette (CE15 test), additional 1.2% gain is reported, both in AI config. It is reported that there is small gain in Class C & D.

It is commented that the CPR with restriction should be tested.

Q: is SIMD used in the test? A: No.

It is commented that the method can be processed in parallel alone diagonal lines

It is also commented that there is still impact on throughput.

It is commented that, line-based intra-prediction method also showed gain in screen content.

The BoG recommended to study in the next CE. (which CE?).

In the follow-up discussion in Track A, it is mentioned that the method deviates from RDPCM of HEVC-RExT, as the latter performs the prediction over the entire block first, and then the quantization. Applying the prediction from adjadent diagonals could introduce severe latency/throughput problems, and does not allow to reuse the (de)quantization/entropy (de)coding stages directly. This should be studied in detail. Put this as sub-CE to “Screen content coding tools” CE. Also test a mode that operates in the same fashion as RDPCM

Unify the previous CPR and palette CEs to one, which contains 1) CPR, 2) Palette 3) Block DPCM

[JVET-L0481](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4585) Crosscheck of JVET-L0078 (AHG11: Block DPCM for Screen Content Coding) [C.-Y. Chen (MediaTek)] [late]

## High-level syntax (31)

Contributions in this category were discussed XXday XX Oct XXXX–XXXX (chaired by XXX).

### General high-level syntax (1)

[JVET-L0110](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4191) On VVC HLS architecture and bitstream structure [S. Wenger (Tencent), Y.-K. Wang (Huawei), M. M. Hannuksela (Nokia), R. Sjöberg (Ericsson), S. Deshpande (Sharp)]

This contribution was reviewed in JVET plenary Wednesday 1830 (GJS & JRO)

This document provides and proposes VVC high-level syntax (HLS) architecture and design rationale. Additionally, a VCC bitstream structure is proposed. Some items are proposed for discussion.

Proposed VVC HLS architecture and design rationale:

1. (Proposal) That the NAL unit concept of AVC and HEVC should stay, as it has proven to be useful, and because at least some system specifications (to include certain file formats) rely on it.
2. (Proposal) The concept of CTU-based (independent, raster-scan-order, with terminating positions unknown after parsing the header data) slices is proposed to be removed, as a vestige of MTU size matching considerations, but tiles (rectangular regions of known size) are proposed to be supported.
   1. Tiles are generally expected to be independently parseable/decodable within the current picture.
3. (Proposal) Independent decoding of motion-constrained tile sets (MCTSs) sets is suggested to be useful for certain application scenarios. Encoding and signalling of MCTSs should be supported.
   1. Note: This could be just a matter of metadata, e.g., as in HEVC.
4. (Proposal) A picture header (which would carry data that applies to the entire picture, but without a picture header ID signalled in the picture header itself hence not referenceable by VCL NAL units) or header parameter set (HPS, which contains header parameters, contains an ID and hence referenceable by VCL NAL units), is proposed to be considered if it has a good impact on BD rate performance.
   1. This is a rate-distortion justified matter; see next item.
5. (Proposal) PPS and SPS are proposed to stay mainly as is, both in terms of syntax (individual NAL units) and functionality and persistence scope.
6. (Proposal) Decoder parameter set (DPS), required to stay constant for the lifetime of a video stream.
   1. This is a matter of maximum capability negotiation, subprofiling, decoder initialization.
7. Thoughts about profiling of tiles
8. Some of the co-authors think that tiling should perhaps be enabled based on profile used. Perhaps, a very basic tiling mechanism, to support straightforward parallelization, could be part of all profiles. More advanced techniques could be specified only for certain profiles. For example, a 360 profile using cube maps could allow motion constrained independent tiles tailored for that application (perhaps in addition to the basic tiles); e.g., 24 motion-constrained tiles as in 6 x 4 arrangement, or in a cross-style arrangement. Other profiles may be applicable to other projection formats.
9. Some of the co-authors think that these decisions are such that should happen later on. Generally, the fewer profiles the better for the success of VVC. Note that in HEVC, only "basic" tiles affected normative operation. Motion-constrained tiles (or tile sets) are constraints that an encoder could choose to use but which don't affect normative decoder behavior.
10. Using the same tool for different purposes is almost always problematic, as encoders need to weight between the needs of the purpose. Some of the co-authors think that this is also true for tiles. For example, if parallelization requires one tile layout, and 360-video related projection requires a different one, what should an encoder do? However, some of the co-authors think that whether different modes or different profiles are needed for tiles may also depend on how diverging is the difference of the desirable tile layouts for different purposes. At least for the ERP and CMP projections, which are most widely used today, aside from some special 360 video optimization scenarios, the flexibility allowed by the tile design in HEVC seems good for both purposes of parallel processing and viewport-dependent 360 video delivery optimization.
11. Thoughts about VPS
12. Some of the co-authors think that VVC first version should have Video Parameter Set (VPS) to tie together scalable layers; a VPS breaks at IDR across layers boundaries. It is preferred to have the VPS from the outset, and not to copy VPS data into the SPS.
13. Some of the co-authors think that maybe it'd OK to not have VPS in VVC version 1, unless multiple-layer is already enabled, which does not seem to be the case.

Based on the above discussions and proposed VVC HLS architecture and design rationale, the contribution proposes that the VVC bitstream structure should comprise of the following NAL units or data structures:

* (Proposal) Decoder parameter set (DPS), required to stay constant for the lifetime of a video stream
  + It was commented that something equivalent might be possible without a new syntax structure – e.g., with repeated elements in the SPS that are constrained to not change.
* (Proposal) Sequence parameter set (SPS) similar in functionality as in HEVC, scope is coded video sequence
* (Proposal) Picture Parameter Set (PPS) similar in functionality as in HEVC, scope is a coded picture. At the same semantic level and similar scope (covering full coded pictures, but can change from coded picture to coded picture)
* (Proposal) Picture Header (carries data that applies to entire picture and that can change from picture to picture, plus reference to PPS) or Header Parameter Set (HPS), if it has a good impact on BD rate performance
* (Proposal) Tile Group Header (TGH)
* (Proposal) VCL data of the VCL NAL unit (tile group) comprising a Tile Group Header (TGH) and Coding Tree Unit (CTU) data of an integer number of tiles
* (Proposal) EOS (end of sequence) and EOB (end of bitstream) with similar functionality to HEVC.
* (Proposal) Prefix and Suffix SEI messages
* (Thoughts) Video Parameter Set to tie together scalable layers; have the VPS from the outset, and don't copy VPS data into the SPS.

Decision on agreements in principle:

* Agreed: NAL units, SPS, tiles, not currently planning to have classical slices
* Do we need to be able to put multiple tiles in one VCL NAL unit? It is a coding efficiency matter whether we would just have one header per tile or also some header for a group of tiles.
* Do we need a maximum capability negotiation header level – something with a persistence scope beyond the CVS? Yes, either this or something like having some SPS syntax elements that are not allowed to change. This would not necessarily need to be carried within the bitstream. It could be repeated. It might or might not directly affect the decoding process (e.g., it could just establish constraints).
* Do we plan to have a PPS (referenceable by multiple pictures) or a (perhaps repeatable) picture header? Yes.

Other aspects are for further study.

### Interoperability and capability points definition and signalling (4)

Contributions in this area were presented Sunday 7 October 1400 (chaired by GJS).

[JVET-L0042](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4123) Example restriction flags for VVC [J. Samuelsson (Divideon)]

This contains an example set of restriction flags that, when implemented in the standard, can be used to disable individual coding tools through syntax elements signalled at the highest level of the bitstream, e.g. in the sequence parameter set. The contribution had previously been discussed to some extent in AHG15.

The syntax elements in the provided syntax are grouped together depending on which part of the standard they relate to. That is purely for the purpose of increased readability and reduced overhead. There is no form of hierarchical restrictions applied. The restrictions are intended to affect the decoding process. For example, when disable\_transform\_cbf is set to 1, there would be no coded block flags present in the bitstream. Some restrictions would result in bypassing a processing step (such as disable\_intra\_ref\_sample\_filter) while others would result in a simple “fallback” alternative is used (such as using DC prediction if a disable\_intra\_planar\_flag is set to 1), but the the contributor said the intention is that all such fallback methods are simple methods already present in the standard, i.e. there would be no need to add new technology in order to handle the fallback.

The proposed flags are at a low level of granularity – e.g., the proposal lists 9 flags to control individual aspects with the deblocking filter.

It was commented that if there are too many “fallback” cases or too many “micro-level” switches, it could be very difficult to test decoders.

In particular, it was commented that the CABAC engine is an example of a part of the design that tends to be highly optimized in implementations, such that it would be difficult to design a decoder that can support a fine granularity of differences in how CABAC operates.

[JVET-L0043](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4124) AHG15: Hierarchical decoding property indications [M. M. Hannuksela (Nokia)]

The contribution proposes a profile\_level( ) syntax structure that has the following parts:

* Profile indicator.
* Size of the extension that follows the constraint and extension flags. The extension contains the syntax elements whose presence are conditioned by the constraint and extension flags.
* Level indicator.
* A fixed number of flags for indicating constraints. These flags do not have an impact on the decoding process.
* A fixed number of flags for indicating extensions or otherwise affecting the decoding process.
* An extension part containing syntax elements are conditionally present depending on values of constraint and extensions flags.

The profile\_level( ) syntax structure is proposed to be included at the beginning of the sequence parameter set syntax. Additionally, it is proposed to indicate profile\_level( ) for an entire bitstream.

In addition, the contribution proposes:

* Including flags for bit depth and chroma format as flags affecting the decoding process in the profile\_level( ) syntax structure.
* Including bit depth, chroma format, and separate colour plane syntax elements in the extension part of the profile\_level( ) syntax structure.
* Excluding bit depth, chroma format, and separate colour plane syntax elements from the "base" syntax of the sequence parameter set.

|  |  |
| --- | --- |
| profile\_level( ) { | **Descriptor** |
| **profile\_idc** | u(5) |
| **reserved\_zero\_3bits** | u(3) |
| **num\_24bit\_extensions** | u(4) |
| **reserved\_zero\_4bits** | u(4) |
| **level\_idc** | u(8) |
| **reserved\_zero\_constraint\_48bits** | u(48) |
| **reserved\_zero\_dec\_48bits** | u(48) |
| if( num24bit\_extensions > 0 ) { |  |
| startBitPos = bitstream\_pointer\_pos( ) |  |
| endBitPos = bitstream\_pointer\_pos( ) |  |
| numStuffingBits = num\_24bit\_extensions \* 24 − ( endBitPos − startBitPos ) |  |
| for( i = 0; i < numStuffingBits; i++ ) |  |
| **reserved\_zero\_bit** | u(1) |
| } |  |
| } |  |

Some flags would affect the decoding process (reserved\_zero\_dec\_48bits) while others do not (reserved\_zero\_constraint\_48bits). Based on which of these contains a flag, a decoder could determine whether the bitstream is decodable or not, since an indication of a constraint would not affect the decoding process, and a constraint could even be added later in a later version of the standard.

It was commented that the num\_24bit\_extensions should perhaps be put later in the syntax structure, and possibly even omitted from v1.

It was commented that having a longer profile\_idc syntax element might be preferable. It was noted that this proposal does not include the “profile compatibility flags” of HEVC.

The fixed length nature of the reserved\_zero\_constraint\_48bits and reserved\_zero\_dec\_48bits was mentioned as an issue. It may be difficult to determine how many of these to provide, without carrying around too much unused overhead.

It was remarked that in HEVC the constraint flags are not necessarily obligated to be used as flags in future use – e.g., a few of them could be used together to send a number.

The non-packed constraint and no-field-pictures flags in HEVC were raised as interesting cases, as these have decodable bitstream that may nevertheless produce pictures that a decoder may not want to use.

Non-flag behaviour was mentioned as a possibility.

The contribution included an example of adding some parameters that affect the decoding process by using a flag to indicate the presence of some other data.

Including user-defined data, e.g., T.35 to avoid collisions, was mentioned as a possibility.

The profile\_level( ) syntax structure is proposed to be included at the beginning of the sequence parameter set syntax.

The top-level syntax would signal a maximum capability. For example, a bitstream might also be allowed to contain data for the same profile at lower levels or lower bit depths or lower chroma formats or data for some “lower” profile.

The concept of “tiers” was not included.

Decisions on agreements in principle:

* It was suggested to agree in principle, as a starting point, to have something at the start of the SPS that indicates properties that cannot be violated in the entire bitstream. Agreed.
* It was suggested to start with presumption that there would be a list of disable flags. Agreed.
* It was suggest to agree in principal that there would a separation between things that affect the syntax or decoding process and things that merely express constraints. Agreed.

[JVET-L0044](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4125) AHG15: Proposed interoperability point syntax [J. Boyce, Z. Deng, S. Wong, L. Xu (Intel)]

A strawman design for signalling constraints in a profile\_tier\_level( ) syntax structure in the SPS is proposed to enable describing decoder capabilities needed to decode a bitstream. It is based upon the VTM2 design in JVET-K1001-v5. The proposed design draws from the concepts proposed in JVET-K0312, and is intended as a starting point for discussion, rather than as a fully finalized solution.

A user-registered subprofile value could be indicated. The proposed size for this was 8 bits (which would limit the number of subprofile values that could exist.

It was discussed that T.35 could be used for this. For example, there could be a fixed length of 4 bytes formatted using T.35 (or always 8 bytes).

It was discussed whether or not it is desirable to omit flags that are not relevant because of the values of some earlier flags.

The concept of having some constraints that apply to the whole bitstream while having lower level syntax to indicate whether a feature is being used on a more localized basis (e.g., within a CVS) was in the contribution.

[JVET-L0270](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4365) Suggested restriction flag criteria [J. Samuelsson (Divideon)]

This contribution suggests criteria for how to define restriction flags in VVC. The contribution includes a section that presents a motivation for restriction flags that includes a description of a hypothetical scenario. The contribution suggests that restriction flags should be defined for all parts of the VVC standard and suggests to aim for a compression efficiency impact in the range of 0.2% to 2% for each individual restriction flag.

Tools with compression efficiency impact above 2% are preferably split in parts with different restriction flags covering different parts so that the different parts can be individually turned off, each with a compression efficiency impact of less than 2%.

It was commented that the criteria may be more multidimensional than a matter of average coding efficiency – e.g., for MBAFF, ASO, and FMO of AVC, the degree of benefit of the feature would depend significantly on the application usage.

[JVET-L0696](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4810) Proposed starting point for interoperability point syntax [J. Boyce (Intel)] [late]

Discussed Thu 11 Oct 1400 (GJS).

This contribution proposes a starting point for the interoperability point syntax, based upon the agreements of design principles during the review of contributions JVET-L0042, JVET-L0043, JVET-L0044, and JVET-L0270.

All proposed constraint flags (yellow highlighted in the proposal) are just constraints, as a starting point. 18 constraint syntax elements are proposed, using 22 bits. These constraint syntax elements are intended to have semantics that apply to the whole bitstream.

One mentioned issue is the implicit nesting of 4:2:2 capability in 4:4:4 capable bitstreams and the implicit nesting of monochrome. This should be further studied.

The proposed scheme does not consider extensibility, which ultimately needs to be considered.

Decision: Adopt.

Regarding the question of whether we have a PPS or picture header or both.

Decision: Use a PPS for now.

The picture header topic as a substitute or additional header is for further study.

Whether to have some picture header is primarily a coding efficiency issue.

Decision: Regarding including some provision for future extensions in the syntax (e.g., multi-layer extension), it was agreed that may do so in cases where this has a very minor impact on the current design.

### Picture partitioning − slicing and tiling (12)

[JVET-L0114](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4195) On slicing and tiling in VVC [Y.-K. Wang, Hendry, J. Chen, M. Sychev (Huawei), M. M. Hannuksela (Nokia)]

This contribution was discussed in Track B on Friday 5 October afternoon (chaired by GJS).

This contribution proposes a design of slicing and tiling for VVC. It is asserted that the proposed slicing and tiling design can be summarized as follows:

* Tiling is basically the same as in HEVC, where a picture may be partitioned into tile columns and rows, and each tile covers a rectangular region of the picture.
* Each slice exclusively contains an integer number of complete tiles covering a rectangular region of a picture.
* Each slice is in its own NAL unit.
* The design enables extracting a set of motion-constrained tile sets (MCTSs) from a bitstream to be a conforming sub-bitstream without the need of rewriting slice headers or any other part of the VCL NAL units.
* Signalling of end\_of\_slice\_flag for each CTU is avoided.

Detailed specification text for the proposal, based on JVET-K1001-v5, is provided as an attachment of this contribution.

Slices are proposed to be groups of tiles, and are proposed to (at least initially) be rectangular groups of tiles. One potential use mentioned for not necessarily be constrained to rectangular regions was for coding a background region separate from an ROI, and another was ultra-low-delay operation.

Extraction of MCTSs without modification of any syntax is proposed, by using the PPS to carry the mapping of the tile ID to the position in the picture.

The bit equal to 1 at the end of a tile was discussed. It was commented that this bit is useful for checking bitstream validity. It is also used to identify the last bit of payload data of a NAL unit.

Tiles can be used for various purposes. Two primary considerations are parallel processing and sub-picture access.

MCTSs have been a focus of a substantial amount of work and application uses recently.

The question of whether multiple tiles are needed in one NAL unit is considered a matter of coding efficiency.

As proposed, the number of tile groups in the picture is established by the PPS (not by syntax in the header of a group of tiles).

Basic questions we need to answer to take action on this proposal:

* Do we need multiple tiles in a NAL unit?
* If yes, is the rectangular constraint desirable?
* If yes, do we need flexibility on how many tiles are in – parameter set level versus establishing that with slice-level syntax
* Need the location remapping functionality?

Further study was encouraged.

[JVET-L0127](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4208) On VVC tile design [Yong He, Yan Ye, Ahmed Hamza (InterDigital)]

This contribution was discussed in Track B on Friday 5 October afternoon (chaired by GJS).

This contribution suggests to consider supporting load balanced parallelism and MCTS-based viewport-dependent 360° streaming in VVC tile design. Several tile partition examples are suggested to be considered when evaluating tile design contributions. This contribution also suggests to re-consider HEVC constraint on the relationship between slices and tiles to enable more flexible tile partitioning, and consider supporting temporal motion-constrained tile set (MCTS) in VVC tile design.

Some of the tilings illustrated in the contribution are not supported in HEVC, due to having some boundary lines that do not span the whole width or height of the picture.

The use of MCTSs was emphasized in the proposal.

The potential for treating tile boundaries as picture boundaries and the potential for having tile dimensions that are not integer multiples of CTUs (not just for the right-most and bottom-most part of the picture) were discussed. Perhaps not even having the left and top boundaries of a tile aligned with CTU boundaries was discussed.

It was commented that there had been a proposal at the previous meeting K0260, also in L0415, that can support the alternative tile structuring.

Introducing extra cuts through the picture can be used to support the illustrated cases, but this would somewhat harm coding efficiency.

[JVET-L0182](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4273) Design goals for tiles [M. M. Hannuksela, A. Zare, M. Homayouni, R. Ghaznavi-Youvalari, A. Aminlou (Nokia)]

This contribution was discussed in Track B on Friday 5 October afternoon (chaired by GJS).

This contribution proposes that the VVC tile design should enable

1. Encoding of motion-constrained tile sets (MCTSs) that are more efficient than HEVC MCTSs in terms of rate-distortion penalty;
2. Avoiding visible MCTS boundaries with as small processing cost as possible;
3. Intra block copy across tiles for enabling prediction from one constituent frame to another for frame-packed stereoscopic video, provided that intra block copy is adopted as a tool in VVC;
4. Extracting VCL NAL units of a subset of MCTSs from one VVC bitstream and reposition them to another VVC bitstream without VCL NAL unit modifications.

The proposed design goals are asserted to make VVC tiles suited for viewport-dependent 360° streaming.

The design goals are proposed to be used in evaluating merits of technical contributions.

The contribution is essentially the same contribution as JVET-K0300.

Item 4 was suggested to be potentially ripe for a decision, reworded as “Extracting VCL NAL units of a subset of MCTSs from one VVC bitstream and reposition them to another VVC bitstream without substantial difficulty (e.g., without VLC-level modifications)”. Decision: Agreed that this is a design goal, subject to having a solution that does not have a large impact on complexity or coding efficiency.

[JVET-L0183](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4274) Header parameter set (HPS) [M. M. Hannuksela, K. Kammachi-Sreedhar (Nokia)]

This contribution was discussed in Track B on Friday 5 October afternoon (chaired by GJS).

Two options are proposed in this contribution:

1. Slice header parameters are selectively included either in the PPS or in the slice header.
2. Slice header parameters are selectively included either in a header parameter set (HPS) or in the slice header. Different HPSs may used in different slices of the same picture.

Option 1 was added to version 3 of the contribution. Option 2 has been been included in the contribution since version 1.

Potential bit rate savings were estimated for monoscopic cubemap-projected 360° 30-Hz video with 96 tiles, each carried in its own slice. Version 2 of the contribution contains a 9-frame example analysis indicating that the proposal reportedly provides 10.0% bit rate saving in luma Bjontegaard delta bit rate. Version 3 of the contribution contains a 32-frame simulation estimating that the proposal provides 14.9% bit rate saving in luma Bjontegaard delta bit rate.

For some use cases as discussed (e.g., viewport dependent streaming), it would be undesirable to group the tiles into large slices.

It was noted that, e.g., for ALF, if the overhead of the parameters becomes substantial, it would be better to just disable the feature than to send its parameters. Repeating ALF parameters several times in a picture would probably do more harm than disabling ALF for the picture.

It was commented that an approach we have used a number of times is to have something that can be sent at a high level with the ability to override or modify it at a lower level (e.g., slice header).

Small variations of the same concepts have come up several times in the past. It seems to be mostly just a coding efficiency and use case question what exact approach we would want to use.

It seems clear that if we keep ALF we will need a way to store its parameters to share their use in multiple VCL NAL units of a picture.

Would different ALF parameters be needed in different parts of the picture?

Would ALF parameters be stored and shared by multiple pictures or coded differentially relative to values used in other pictures?

Further study encouraged.

[JVET-L0202](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4293) HLS for spatial relation between independent VVC sub bitstreams [E. Thomas, A. Gabriel (TNO)]

This contribution elaborates on JCTVC-AB0032 and proposes a method for defining independent sub video bit streams depicting spatial regions of a video which constitute together a single bitstream. In the context of this document, these independent sub video bit streams are called tiles in the contribution, but they are orthogonal to the current HEVC tile features. A parameter set called tile-positioning parameter set (TPS) is proposed which is pointed by the sequence parameter set (SPS) and links to a possible video parameter set (VPS). A TPS permits describing the relation between different tiles by using the concept of hooks. Hooks permit describing the relative position, hence not absolute, between tiles without a coordinate system. A pair of matching hook identifiers would express that two tiles are neighbours along a certain border. Having no matching hook identifiers would express the absence of spatial relationship between two tiles.

Having more flexible tile layout (“non-grid” arrangements) than what is supported in HEVC is envisioned.

Different regions of the picture would be coded independently through time. There would be different “sub-bitstreams” for these regions. These regions could have their own SPSs and PPSs.

There could be different resolutions in different regions of the picture.

The TPS would establish an arrangement of the relevant tiles. It would be a very high level syntax structure.

This has some similarities with MCTS extraction and rewriting concepts. However, it goes further into the domain of handling multiple independent bitstreams, which has generally been considered a system functionality. It was commented that this may be more like a system functionality – e.g., sub-picture track groupings as used by OMAF.

This seems potentially out of scope and should be considered by systems experts for feedback before further consideration here.

[JVET-L0227](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4318) AHG 12: Sub-bitstream extraction/merging friendly slice address signalling [R. Skupin, Y. Sanchez, K. Sühring, T. Schierl, T. Wiegand (HHI)]

The extraction or merging of MCTS sub-bitstreams in HEVC is cumbersome, as potentially all slice headers need to be rewritten. This document proposes changes to the slice\_address signalling in VVC in order to allow extraction or merging of MCTS based sub-bitstreams without the necessity of slice header changes.

The proposal is to signal slice addresses in slice headers

* relative to the first CTU of a tile
* in tile scan order
* code slice address depending on tile size

wherein tile refers to a rectangular group of CTUs.

“Final” slice address in raster scan order within the picture are derived through adding a per-tile slice base address given from the tiling structure. As there is currently no tiling syntax in VVC, the presented syntax changes rely on an HEVC-style tiling syntax.

As the current VVC design requires parameter set parsing for access unit boundary detection, this document in addition proposes to integrate an access unit delimiter NAL unit and to mandate its use when the proposed slice address signalling scheme is enabled.

Some of this is about how traditional slices can be used with tiles, i.e., how to deal with multiple slices in a tile. It is generally focused on slices that don’t cross tile boundaries but rather lie within individual tiles. At the moment, such a form of traditional slices are not planned to be supported in VVC.

We should keep this approach in mind if we choose to go back on the idea of not supporting multiple slices within tiles.

[JVET-L0306](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4401) On slices and tiles [M. M. Hannuksela (Nokia)]

This contribution proposes that

1. The concept of raster-scan-order slices is removed from VVC.
2. The concept of tiles (as known in HEVC) is included in VVC.
3. A tile grid is indicated in the PPS as in HEVC.
4. A slice contains one or more complete tiles in row-major order of tiles.
5. The slice header contains a tile\_id value indicating the first tile in the slice in decoding order. slice\_address is proposed to be removed from the slice header.
6. Rather than being present after each CTU, end\_of\_slice\_flag is present only after each tile in slice\_data( ).

This proposal is similar to the current HEVC multi-tile slice, with a flag to indicate that no additional tiles are included in the slice.

Entry points are not part of the proposal.

The proposal is a straightforward somewhat minimalistic approach to slices with tile granularity. The proponent indicated that this approach is not necessarily preferred over the rectangular slice proposal of L0114, but was provided as a simple starting point.

[JVET-L0359](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4456) AHG12: Flexible tile partitioning [Y. Yasugi, T. Ikai (Sharp)]

This contribution is relevant to the tile functionality proposed in JVET-K0155. The proposed tile allows to split a picture into flexible partitioning tiles, where the width or height of the unit of tile can be multiplies of 4 (the minimum CU size), 8, 16, 32 and 64, i.e. smaller than CTU. By using partial CTUs on the right and bottom edges of each tile, a picture can be divided into tiles of more uniform size and this functionality reportedly helps better load balancing. Furthermore, it is also asserted that this feature is useful for 360 video sequences and frame packing sequences since the corresponding tile can fit the arbitrary rectangular face size. The authors implemented the proposed tile on VTM-2.0.1 with support of LFCrossTileBoundaryFlag in adaptive loop filter (ALF) and evaluated the performance.

The experimental results with this feature (unit=32) reportedly show that luma BD-rate coding losses on average are 0.85% % for All Intra and 1.45% % for Random Access under the common test condition (CTC) for SDR sequences excluding padding data added by CABAC.

The experimental results without this feature (i.e. HEVC like tile) reportedly show that luma BD-rate coding losses on average are 0.82 % for All Intra and 1.37 % for Random Access under the common test condition (CTC) for SDR sequences excluding padding data added by CABAC.

This basically proposes treating the right edge of a tile as the right edge of a picture for the decoding of each tile, except perhaps for inter prediction references to positions in reference pictures. The positions of CTUs in the picture would not be on a CTU grid anymore. Whenever a new tile would start, a new CTU would start at that position. The number of CTUs in a picture would become somewhat larger. Some constraints on minimum tile sizes might need to be imposed.

An example use case that was discussed was 360° video with face sizes desired not to be a multiple of the CTU size.

This seemed intriguing.

It was noted that if the positions of the tile boundaries change from picture to picture, the positions of CTU boundaries in a picture might not be at CTU boundaries in the reference pictures.

This was further discussed Thursday 11 October 1320 (GJS).

Draft text was provided.

It was noted that an encoder can use smaller CTUs as one way to provide finer tile granularity.

It was commented that if this is motivated by load balancing, it does not seem so interesting for that purpose. However, it was suggested that this can be useful for certain applications such as cubemap coding.

It was suggested that a level limit could be established for how many CTUs (counting partial CTUs as full CTUs) are in a picture rather than the width and height of the picture, or otherwise to limit how many partial CTUs need to be processed).

Two other aspects may need to be considered:

* Whether the boundaries are padded when using MVs to reference areas outside the tile (or tile group) in reference pictures. The proposal does not propose padding.
* Whether the CTU positions in a reference picture are at the same place as in the current picture. This may not be an issue, as long as the boundaries are on an 8x8 basis (due to storage of MV data for TMVP on an 8x8 basis).

This seems conceptually OK, and likely to be useful for some applications. It was commented that the software looks good.

The group was inclined to adopt this, but planned to wait one meeting cycle for study to confirm that no problems are identified.

[JVET-L0635](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4748) Cross-check of L0359: AHG12: Flexible tile partitioning [T. Hinz (HHI)] [late]

[JVET-L0374](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4471) On Tile Information Signalling for VVC [S. Deshpande, Y. Yasugi (Sharp)]

Syntax, semantics and decoding process is proposed for VVC for tile information signalling. The proposed approach includes signalling of tiles and tile sets.

This has substantial similarities with the Huawei-Nokia proposal.

High level description of the proposed approach is as follows:

* Information regarding tile structure for a picture is signaled in parameter set: For this currently all HEVC syntax elements in PPS are proposed to be included.
* Optional information regarding tile sets is signaled in parameter sets: This information helps creation of slices, allows knowing the tile set structure in advance, and in turn enables parallel decoding of tile sets (described further in the next point).
* Coding tree block and tile scanning conversion process: Process from HEVC is adopted and modified to support tile sets. The raster ordering of coded tree blocks (CTBs/ CTUs) is row-by-row in tile raster scan within a tile set and the tile sets themselves are raster ordered within the picture. The proposed approach makes the coded data within a tile set contiguous which can help extraction of the tile set portion of the bitstream and parallel decoding and/or sub-bitstream extraction of those bitstream portions.
* A slice (or a segment or a tile group) consists of header and data for a single complete tile set. Slice (or a segment or a tile group) header signalling consists of signalling of a tile set identifier and entry point signalling for tiles within the tile set.

The tile sets are proposed to have a grid structure, like the assignment of CTUs to tiles. The possibility of greater flexibility than such a grid structure, either for the assignment of CTUs to tiles or for assignment of tiles to tile groups, was discussed.

A participant commented that stitching of data together to form a single bitstream is sometimes needed rather than the handling of different bitstreams separately.

An example layout is multipoint conferencing with a large rectangle for the presenter and

With the tile sets established at the parameter set level, the ID sent at the slice level is proposed to indicate which tile set is in the slice.

[JVET-L0394](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4491) On Conflicting Use of Tiles [S. Wenger (Tencent)]

Proposed are a) a tile hierarchy intended to reconcile possibly contradicting requirements imposed on the tile layout by application and parallelization needs, and b) a set of flags that, for each hierarchy level in the tile hierarchy, specify which prediction mechanisms are broken across tile boundaries.

The tile layout that would be motivated by a desire for parallelization is different from what would be desired for other reasons.

The contribution suggests considering having different types of control over the properties of tiles and considering having flags to control over what sorts of prediction mechanisms are broken at tile boundaries.

It was commented that the entry points into the decoding process in HEVC are coupled with the data layout and the locations where the prediction operations are broken.

[JVET-L0415](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4513) Tile groups for VVC [R. Sjöberg, M. Damghanian, M. Pettersson (Ericsson)]

This contribution proposes that tiles are adopted into VVC and that slices in VVC consist of an integer number of complete tiles instead of consisting of an integer number of complete CTUs.

The following is proposed:

* Adopt tiles into the VVC draft (HEVC tiles or flexible tiles as in JVET-K0260)
* Change the name of slices to tile groups. Keep the slice header but call it tile group header
* Replace the slice address by a tile group address in the tile group header
  + This means that the existing slices become tile groups that always contain an integer number of complete tiles
  + This also means that raster-scan CTU slices are no longer supported
* Add a syntax element num\_tiles\_in\_tile\_group that specifies the number of tiles there is in the tile group. This is used both for the decoder to know when the tile group ends and to know how many tile pointers there are in the tile group header
* Remove the end\_of\_slice\_flag syntax element, instead the end of the tile group is given by the tile group address and the num\_tiles\_in\_tile\_group code word.

This is proposed as a starting point for tiles.

The number of tiles in a tile group is established in the NAL unit level syntax rather than at the parameter set level.

Entry points are proposed to be provided for every tile, which makes it necessary to know how many tiles will be in the “tile group”.

This proposes to adopt tiles into VVC (which had already been agreed earlier in the meeting).

Change slice to “tile groups” (editorial)

Use a tile group address.

similar to L0306.

It was initially agreed to support multiple tiles in a tile group (otherwise tiles would be forced to be larger than necessary). As a starting point, a tile group is a string of tiles starting at a tile address in raster order and ending where indicated by a tile-level ending flag that is otherwise similar to the HEVC CTU-level more\_data\_in\_slice\_flag. Software implementation in a timely manner is required. Text is per L0306.

In the Sunday morning plenary (see section 12.1), it was agreed that instead of ending each tile with a more\_data\_in\_group\_flag, we would indicate the number of tiles in the tile group header and provide entry points to the start of each tile. This was further discussed and confirmed Thursday 11 October 1245 (GJS).

Various aspects remained to be further studied – potentially rectangular shape, potentially non-grid layouts, etc., TBD.

This is just a starting point – the raster order aspect has no presumptive status.

[JVET-L0686](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4800) Spec text for the agreed starting point on slicing and tiling [Y.-K. Wang, Hendry (Huawei), R. Sjöberg (Ericsson), S. Deshpande (Sharp)] [late]

This was discussed Thu 11 Oct 1300 (GJS).

Draft text was provided. Basically, everything that had been at the slice header level was put at the tile group header level (e.g., I versus B versus P slice type).

It was discussed whether to put the entry point offsets earlier in the header to avoid excessive parsing to get to the information, e.g., immediately after the num\_tiles\_in\_tile\_group\_minus1 syntax element, but this was deferred for further consideration. It was agreed to condition the presence of num\_tiles\_in\_tile\_group\_minus1 on whether there is more than one tile in the picture. There was a bug in the tile group data syntax, since it would need both a loop for the number of tiles and, for each tile, the number of CTUs in the tile. Decision: Adopted (as modified).

### Reference picture management (9)

Discussed Monday 1815 (GJS)

[JVET-L0112](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4193) On reference picture management for VVC [Y.-K. Wang, Hendry (Huawei)]

This contribution proposes a reference picture management approach for VVC based on direct signalling and derivation of reference picture lists 0 and 1, without use of reference picture set (RPS) as in HEVC or the sliding window plus memory management control operation (MMCO) process as in AVC.

The proponent asserted that the proposed approach is significantly simpler compared to the approaches in HEVC and AVC (both for text and software).

On signalling overhead, when only one SPS and only one PPS are used, the following results were reported for the different CTC configurations:

For the CTC configurations, the proposal generally has about twice the overhead at the SPS level (about 60 bytes more) and about the same amount at the PPS and slice header level. A substantial part of this was reported to be because the proposal does not use the “inter-RPS prediction” technique found in the HEVC SPS syntax.

A redundancy was noticed in the syntax for signalling a sign when the value is 0.

For unused pictures, they are placed in the two lists rather than being listed separately as in the L0450 proposal.

One participant commented that there may be some robustness issue for the long-term reference picture handling.

See also L0113 for a related contribution on non-normative encoding configuration.

[JVET-L0592](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4705) Crosscheck of JVET-L0112 (On reference picture management for VVC) [Y. Kidani, K. Kawamura, S. Naito (KDDI)] [late]

[JVET-L0616](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4729) Cross-check of JVET-L0112 and JVET-L0113 [K. Misra] [late]

[JVET-L0416](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4514) Simplified RPS for VVC [R.Sjöberg, M. Damghanian, M. Pettersson (Ericsson)]

In this contribution it is proposed that a minimal reference picture set (RPS) is adopted into the VVC draft as a starting point. The proposal suggests that text based on the HEVC v5 RPS text is used, with removal of inter-RPS, HEVC long-term pictures and text related to syntax elements not present in the current VVC draft. In a second version of this proposal, a new long-term picture referencing mechanism is proposed.

Text from the following parts of the HEVC v5 specification is proposed to be included into the VVC draft:

* Definitions: Add definitions of DPB, long-term reference picture, reference picture, reference picture set (RPS) and short-term reference picture set
* SPS: Add syntax and semantics for 2 RPS SPS syntax element (there are 6 syntax elements related to RPS in HEVC)
* PPS: Add syntax and semantics for 3 reference picture lists syntax elements (3 in HEVC)
* Slice header: Add syntax and semantics for 9 slice header syntax elements (12 in HEVC)
* Reference picture lists modification: Add syntax and semantics for 4 syntax elements (4 in HEVC)
* RPS: Add syntax and semantics for 6 syntax elements that can be present in SPS and/or slice header (12 in HEVC)
* Decoding process: Add the decoding processes for picture (general decoding process), NAL units, reference picture set and reference picture lists

The proposed text was provided as an attachment with the contribution. Note that text proposed for picture order count is proposed in JVET-L0249.

The proponents said that inter-RPS is beneficial for reducing the bit cost, but do not propose to include it into the VVC draft at this point. The authors propose to keep inter-RPS in the software for further study.

As proposed, it does not support current-picture referencing, but it is suggested that this would not be difficult to add.

The primary change relative to HEVC, aside from removing inter-RPS, is the handling of long-term pictures.

The proposed long-term picture handling is somewhat less bit efficient than in HEVC. MSBs always need to be sent, and the data for that could grow as the POC distance gets large.

The following restriction flags for turning off RPS features are identified by the proponents as candidates to be discussed:

* long\_term\_reference\_pictures\_disable\_flag
* reference\_picture\_lists\_modifications\_disable\_flag
* inter\_RPS\_disable\_flag

[JVET-L0450](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4550) On Reference Pictures Signalling and Management for VVC [S. Deshpande (Sharp)] [late]

Syntax, semantics and decoding process is proposed for VVC for reference picture management. The proposed approach directly signals reference picture lists for reference picture management. Revision r1 has text modifications for the reference picture list construction.

Similar to L0112, picture lists are signalled directly. Some candidate reference picture lists are proposed to be signalled in the SPS.

As proposed, only one reference picture list order can be signalled, based on POC.

Inactive pictures are listed in a third list.

LTRP signalling is somewhat similar to what is in HEVC.

Discussion

In general, the proposals that signal the RPLs directly may be somewhat less bit efficient as a basic approach, but can be somewhat more straightforward.

It was commented that the HEVC scheme seems to work pretty well, and could be a good starting point – perhaps with removal of the inter-RPS feature for the sake of simplicity (although that feature did have some advantage).

The syntax for RPS and number of active entries in lists in HEVC is repeated in every slice header, and is required to be the same. In the CTC, this is minor because this can refer to SPS-level candidates.

All three of the new proposals and also the HEVC design have some form of index usage at the slice level to refer to something set up at the SPS level.

A participant commented that we might need to consider the implications of multi-hypothesis usage, which could involve more lists.

Further study in an AHG was planned.

### Picture order count (2)

[JVET-L0249](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4342) Picture order count for VVC [R. Sjöberg, M. Damghanian, M. Pettersson (Ericsson)]

See also L0112, which has a POC aspect that is equivalent.

This was discussed Wed 10 Oct. 1620 Track B

This contribution proposes that picture order count (POC) as it is in HEVC is adopted into the VVC draft. It is claimed that deriving relative output distances is vital for deriving motion vector predictors by scaling and the proponents claimed that POC has proven to be a well tested provider of that functionality.

It was proposed that syntax and semantics for two code words be added:

* The signalling of POC LSB in the slice header (slice\_pic\_order\_cnt\_lsb)
* The signalling of the number of bits to use for the POC LSB syntax element (log2\_max\_pic\_order\_cnt\_lsb\_minus4) in the SPS.

This was also basically identical to POC type 0 in AVC.

The only changes relative to HEVC that were included was removing treatment of special picture types that we don’t have in VVC.

Decision: Agreed except as noted below regarding L0449.

[JVET-L0449](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4549) On Picture Order Count Signalling for VVC [S. Deshpande, B. Choi (Sharp)] [late]

This was discussed Wed 10 Oct. 1630 Track B

Picture order count signalling and decoding is proposed for VVC. In r1 of the proposal, some modifications are made to the signalling and constraints.

1. It was proposed that the design should allow signalling of POC least-significant bit (LSB) values for all picture types. The lack of this was asserted to have caused problems for HEVC when it scalability extensions were created.

There was discussion of what the POC means (if anything) for an IDR picture in single-layer operation. The presence of an IDR picture would set the MSBs to zero and there would be no relationship between the POC values of different coded video sequences. The lack of MSBs had caused substantial difficulty in the layered coding (SHVC, MV-HEVC) design.

It was commented that this could also be helpful for alignment of multiple sub-bitstreams.

It was commented that various other work has used layering concepts even outside of ordinary scalability scenarios (3DOF+, 6DOF).

It was commented that the reference encoder relies on the POC of an IDR picture being zero. Software had not been provided.

It was commented that sending POC MSBs could make bitstream editing easier by allowing a picture to be converted from a non-IDR picture to an IDR picture without changing how the prediction of other pictures would operate.

See also L0064, which uses a definition of IRAP that needs POC on the the IRAP.

Decision: Adopted. The MSBs will still reset to zero at an IRAP and there will be no relation between POCs of different CVSs. (Currently the text does not have a non-IDR IRAP.) However, the software will need changes for this. For now, we can just have the encoder use 0 for the IDRs, but we need to put support for this into the software eventually. The contributor volunteered to work on that.

1. It was proposed to have a variation in which there are no MSBs needed (due to a promise that there will be no wrapping).
2. It was proposed to add syntax in the SPS to optionally enable a signalling of MSBs (and having a variable number of MSBs), and be able to signal the MSBs or not on a lower level basis.

No immediate action was taken on the 2nd and 3rd aspects; further study was encouraged.

### Intra refresh (4)

[JVET-L0079](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4160) AHG14: Study of methods for progressive intra refresh [K. Kazui (Fujitsu)]

This contribution reports possible methods for progressive (or gradual) intra refresh, according to the mandates of AHG14 “Low-latency random access”. Firstly, essential restrictions on encoding and possible non-normative methods on the VTM2.0 and BMS2.0 tools for perfect reconstruction (i.e. exact match) at a recovery point picture are studied. Then one of possible normative methods to theoretically mitigate the loss of coding efficiency caused by the restrictions on encoding is suggested.

* Possible non-normative methods on VVC tools
  + ATMVP
  + Intra prediction (incl. CPR)
  + Inter prediction
  + In-loop filtering (Deblocking, SAO, ALF)
* Possible normative method
  + Prohibiting reference across clean region boundary

The recovery point SEI message is used with HEVC to indicate recovery points.

Latency is desired to be reduced by avoiding I frames.

In HEVC, there is also the ultra-low-delay HRD operation.

Simple partial-picture refresh approaches include “vertically long” and “vertically long” approaches.

With CTU-line slices, the horizontal approach puts some I CTUs in each slice, so that no slice is substantially larger than the others.

Disabling TMVP prediction across random-access pictures can be used (in HEVC there is slice\_temporal\_mvp\_enable\_flag).

Intra prediction for some modes uses upper-right neighbours (within the slice), which can also be an issue.

It was noted that this issue does not apply to tiles, and we do not plan to have slices.

In-loop filtering can also “contaminate” picture regions, and deblocking can only be disabled at slice boundaries (SAO and ALF can be disabled on CTU basis).

Non-normative methods

|  |  |  |
| --- | --- | --- |
| **Tool** | **Method** | **Applied to** |
| ATMVP | slice\_temporal\_mvp\_enable\_flag = 0 | R-Access picture |
| Intra | constrained\_intra\_pred\_flag = 1 | Every picture |
| Limited prediction mode | Clean CU near boundary |
| Slice boundary insertion(\*1) | Clean CTU at boundary |
| CPR | Limited search range | Clean CU |
| Inter | Limited search range | Clean CU |
| SAO | Disable edge offset mode | Clean CTU at boundary |
| Slice boundary insertion(\*1) | Clean CTU at boundary |
| DF | Slice boundary insertion(\*1) | Clean CTU at boundary |
| Insert semi-dirty region | Every picture |
| ALF(\*2) | Disable ALF | Clean CTU at boundary |

(\*1) Only effective when clean region boundary is on the CTU grid

(\*2) ALF in Draft 2.0

The contributor’s company uses this sort of refresh. Examples of applications where this was remarked to be relevant include low-latency display, real-time communication, gaming streaming, and surveillance.

Non-normative approaches work, but having a normative approach was suggested to be supported. The large CTU size for VVC was said to be an aggravating factor.

It was commented that smaller CTU sizes may tend to be used for very low delay applications.

* It was suggested for tools in VVC to be restricted for exact match at a recovery point picture in progressive intra refresh
* Some non-normative methods exist, but may have penalties.
* Theoretically, normative clean region boundary can mitigate loss.
* Suggestion to next round of AHG14
  + To develop VTM software for progressive intra refresh with most suitable non-normative methods.
  + To discuss normative methods further.

Using weighted prediction was mentioned as another trick that can be used to attenuate the contribution of a “dirty” region while providing coding efficiency (although not with an exact match).

It was remarked that L0394 may be relevant in terms of being able to switch on and off particular features at boundaries.

Contributions relating to 360° video also have some interaction with this.

To consider a normative approach we would need to show that it provides coding efficiency benefit that cannot be reasonably achieved in some other way.

It was noted that normative approaches would not be required if the encoder can be relied upon to not do things that would cause problems. Appropriate indicators (e.g., SEI) can be considered.

Further study in an AHG was planned.

[JVET-L0160](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4241) AHG14: Intra Refresh Anchor Proposal [J.-M. Thiesse, D. Nicholson, D. Gommelet] [late]

This contribution proposes encoder-only modifications and test conditions to be used as reference for studying intra refresh normative modifications. After describing the encoder modifications and the proposed test conditions, results are reported against a low-delay reference with a comparable intra period. Significant objective losses of 32.61% in luma are reported.

The authors recommend to integrate the proposed encoder modifications in the VTM software and to use the proposed test conditions for studying normative intra refresh proposals.

The software modifications include:

* Intra prediction mode forced on coding units on column basis.
* Constrained Intra Prediction enabled to ensure reconstruction of Intra CU.
* Motion vectors constrained to point within the refreshed area while taking into account an additional margin to avoid interpolation filters spreading error (6 luma samples for instance).
* Removing of former reference pictures when re-looping the intra column.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Low delay B Intra Refresh Main10** | | | | |
|  | **Reference is LB with intra period of 32** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 |  |  |  |  |  |
| Class A2 |  |  |  |  |  |
| Class B | 17,40% | 36,88% | 56,97% | 133% | #DIV/0! |
| Class C | 22,14% | 32,03% | 34,76% | 130% | #DIV/0! |
| Class E | 71,91% | 98,70% | 108,36% | 159% | #DIV/0! |
| **Overall** | **32,61%** | **50,72%** | **62,41%** | **138%** | #DIV/0! |
| Class D | 24,57% | 41,63% | 46,01% | 140% | #DIV/0! |
| Class F (optional) | 53,14% | 58,97% | 61,11% | 164% | #DIV/0! |

This used a granularity of the refresh area is a CU line.

Now we emphasize tiles, which can be used to address some of these issues. The test did not use tiles.

This was using whole-picture slices.

It was suggested to use a different QP and other sorts of RDO to avoid visibility of the refresh region boundaries.

The patch was said to involve about 100 lines of code, touching perhaps 10 files.

It was suggested that an AHG could create branches of the software for AHG testing. The AHG can study this method and others. This scheme is not necessarily considered an anchor in that work.

It was suggested that type of content used for testing such schemes might need to be different, to reflect the intended applications.

It was remarked that we really need the tile approach that was agreed at this meeting to be implemented in the VTM software.

[JVET-L0637](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4750) Crosscheck of JVET-L0160 "AHG14: Intra Refresh Test conditions and Anchors generation Proposal" [K. Kazui (Fujitsu)] [late]

The cross-check used a binary file, not source code.

The cross-checker suggested to modify the decoder software to emulate random access behaviour, and suggested to use the decoded picture hash SEI message to check picture recovery.

It was commented that having packet loss simulation software could also be helpful for experiments.

[JVET-L0161](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4242) AHG14: Normative Intra Refresh Proposal [J.-M. Thiesse, D. Nicholson, D. Gommelet] [late]

This contribution studies the integration of a normative handling of intra refresh into VVC. This is an answer to the last mandate of the AhG14 on low-latency random access. The proposed modification includes signalling intra refresh CUs with syntax at the PPS and slice header level. Those CUs are then encoded according to this knowledge (non-transmission of prediction mode, activation of CIP only on those CUs, and disabling of deblocking filters at the intra refresh boundary).

The reported performance against the non-normative intra refresh method proposed in JVET-L0160 reportedly shows a coding efficiency improvement of 5.26% for LB.

The contributor recommended further study in an AHG, which was agreed.

### Misc. HLS topics (2)

[JVET-L0064](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4145) Simplified NAL Unit Header and IRAP pictures [G. Ryu, W. Choi, M. W. Park, K. Choi, Y. Park, K. P. Choi (Samsung)]

This document describes a high level syntax and semantics for random access. A high level syntax on NAL unit header and NAL unit type are proposed.

As proposed, an “IRAP” would be allowed to have (non-decodable) leading pictures.

Trailing pictures would not be allowed to reference leading pictures.

The proposal basically equates an IRAP picture with a CRA picture.

It was remarked that decodability properties can be signalled by other data such as SEI message data.

It proposes to have a way to indicate IDR versus CRA behaviour in the NAL unit header.

Decision of agreements in principle:

* It was was agreed that we need at least this functionality.
* It was also agreed that some basic picture type information (including open/closed prediction structuring) should be in the NAL unit header (not just an SEI message).

No specific draft text was provided (e.g., to express the details of the semantics).

Further is needed to determine whether more than 3 types are needed and exact syntax and semantics.

[JVET-L0248](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4341) TemporalId restrictions [R. Sjöberg, M. Damghanian, M. Pettersson (Ericsson)]

A basic syntax and semantics for supporting temporal layers was adopted at the 11th meeting in Ljubljana. However, the proponents of this contribution claim that the VVC draft can be improved by adding some additional definitions and restrictions. It is proposed to add text from HEVC adapted for the VVC high-level syntax.

The following elements are proposed to be added to the VVC draft:

1. Definition of sub-bitstream extraction process
2. The following restriction to the semantics of slice\_pic\_parameter\_set\_id: “It is a requirement of bitstream conformance that the value of TemporalId of the PPS that has pps\_pic\_parameter\_set\_id equal to slice\_pic\_parameter\_set\_id shall be less than or equal to the value of TemporalId of the current picture.”
3. The sub-bitstream extraction process with restrictions as shown in italics below

*Inputs to this process are a bitstream and a target highest TemporalId value tIdTarget.*

*Output of this process is a sub-bitstream.*

*It is a requirement of bitstream conformance that any output sub-bitstream that is the output of the process specified in this clause with tIdTarget equal to any value in the range of 0 to 6, inclusive, shall be a conforming bitstream and fulfill the following:*

* *The output sub-bitstream shall contain at least one VCL NAL unit.*
* *The decoded sample values of a picture shall be identical for any value of tIdTarget in the range of 0 to tId, where tId is the TemporalId of the picture.*

*The output sub-bitstream is derived as follows:*

*– Remove all NAL units with TemporalId greater than tIdTarget.*

Point 1 is editorial.

Decision: Point 2 is agreed, if applicable (i.e., if we have PPSs). Regarding point 3, it is agreed to prohibit referencing any picture in a higher temporal sublayer.

Definition of sub-bitstream extraction is for further study.

## PCM (2)

Contributions in this category were discussed Tuesday 9 Oct 1800–2000 (Track A chaired by F. Bossen).

[JVET-L0209](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4300) PCM mode with dual tree partition [Y.-C. Sun, J. An, J. Lou (Alibaba)]

This document proposes PCM mode modification for separated tree partition. The proposed modification is tested on top of VTM2.0.1. In AI/RA/LDB configuration, the results show 0.02%/0.01%/-0.03% BD-rate luma difference.

VTM software has encoder/decoder mismatch when using separate tree partition.

Proposes to include PCM in VVC. It is claimed to be a straightforward adaptation from HEVC (need to adapt to deal with separate tree).

Decision: Adopt.

[JVET-L0533](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4641) Crosscheck of L0209: PCM mode with dual tree partition [[Y.-W. Chen](mailto:yiwenchen@kwai.com), X. Wang (Kwai Inc.)] [late]

## QP handling (4)

Contributions in this category were discussed Tuesday 9 Oct 1800–2000 (Track A chaired by F. Bossen).

[JVET-L0362](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4459) Quantization parameter signalling [Y. Zhao, H. Yang, J. Chen (Huawei)]

The concept of quantization group (QG) was introduced in HEVC for signalling QP for non-overlapped square regions in a coding picture. The QG size can be decided by an encoder for the trade-off between QP signalling overhead and picture quality improvement. A quantization group may contain multiple CUs while CU larger than quantization group is also supported. However, the concept of quantization group breaks in current design of VVC in that a quantization group may contain multiple incomplete CUs, due to non-square CUs. Two mechanisms are introduced in this contribution to extend the concept of quantization group in the context of QT-MTT partitioning framework. The two methods are tested with CU-level perceptually-optimized delta QP calculation as described in CE7.2.3, with MaxCuDQPDepth = 2 and 4.

Q: why use depth instead of area? Several experts commented that it may be better to use area instead of depth. It was commented that there are some complications with TT splits when considering area.

Two methods are proposed. They differ in how they define depth to QP signalling purpose. The first method considers QT, BT and TT splits to determine depth. The second method considers only QT splits.

It was remarked that method 1 is closer to what is already implemented in VTM.

Decision: Adopt method 1 (depth is QT depth + BT depth)

[JVET-L0595](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4708) Crosscheck of JVET-L0362 (Quantization parameter signalling) [Y. Kidani, K. Kawamura, S. Naito (KDDI)] [late]

[JVET-L0428](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4527) Delta QP and Chroma QP Offset for Separate Tree [R. Chernyak, A. Karabutov, S. Ikonin, T. Solovyev, J. Chen (Huawei)]

This contribution proposes a scheme of applying delta QP and Chroma QP offset mechanisms into VVC codec, taking into account separate tree mechanism. More specific, the contribution proposes a unified methods for delta QP and Chroma QP offset usage, regardless of certain type of partitioning tree.

There are two aspects:

* delta QP signalling / QP management when separate trees are used
* chroma delta QP

Q: When separate trees are used, which collocated luma position should be used to derive the chroma QP value? Proposal suggests using top-left position within chroma CU, but it was remarked that it should be consistent with what is done for intra prediction which uses centered reference (see JVET-L0053). Agreed.

Decision: Adopt first aspect (use centered position to fetch collocated luma QP).

On second aspect: need more time and experts to review. Resubmission to next meeting was encouraged.

[JVET-L0553](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4662) Fix of Initial QP Signalling [X. Li, X. Xu, S. Liu (Tencent), Y. Li, Z. Liu, Z. Chen (Wuhan Univ.)] [late]

Max QP was extended from 51 to 63 in Ljubljana meeting. However, the signalling of initial QP was not changed accordingly. Two fixes are proposed in this contribution. It is reported that the second fix is with less changes and more practical.

Decision (bug fix): Adopt second fix to semantics of init\_qp\_minus26 where +25 is changed to +37

# Complexity analysis and reduction (0)

Contributions in this category were discussed XXday XX Oct XXXX–XXXX (chaired by XXX).

# Encoder optimization (3)

Contributions in this category were discussed Tuesday 9 Oct 1800–2000 (Track A chaired by F. Bossen).

[JVET-L0113](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4194) On final reference picture lists in the CTC random access simulation [Hendry, Y.-K. Wang, J. Chen (Huawei)]

This contribution was discussed in Track B 2050 Monday (GJS).

See also L0112.

This contribution proposes a change to the reference picture lists for the CTC random access simulation. It was asserted that having reference pictures with POC values that are both less and greater than the POC of the current picture in a final reference picture list (i.e., either reference picture list L0 or reference picture list L1) does not give a compression benefit in the CTC. It is proposed to simplify the reference picture lists for random access simulations such that a reference picture list contains reference pictures with POC values that all are either less or greater than the POC of the current picture. Simulation results reportedly show performance gain in average −0.19%, −0.26% and −0.26% for Y, U and V, respectively. It was also reported that the proposed change also provides a small reduction to overall average encoding time, which is 2%. This is a non-normative encoder-only change.

This could also be relevant to the HM. Other optimizations discussed included encoder optimization of list order based on analysis of of usage of the reference indexes (such a technique was said to be in the HM). Further study would be interesting.

[JVET-L0593](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4706) Crosscheck of JVET-L0113 (On final reference picture lists in the CTC random access simulation) Y. Kidani, K. Kawamura, S. Naito (KDDI) [late]

See also L0616 for another cross-check.

[JVET-L0181](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4272) AHG10: Corrected operation of ALF encoding with perceptually optimized QP adaptation [C. Helmrich, B. Bross, J. Erfurt (HHI)]

In JVET-H0047, the authors proposed a CTU-wise subjectively optimized QP adaptation (QPA) along with a correspondingly weighted PSNR (WPSNR) distortion measure.This QPA approach was further improved in JVET-K0206 and accepted for integration into (and optional activation in) the VTM/BMS software.

While studying the adaptive loop filter (ALF) recently integrated into the VTM/BMS software, the authors noticed that the respective encoder-side algorithms and decisions related to the CTU-wise (de)activation of the ALF tool depend on a Lagrangian parameter derived from the *fixed slice-wise* QP, i.e., the associated with the given slice.This document proposes to utilize, instead of , a *CTU-wise* Lagrange parameter in the CTU related ALF encoding algorithms and decisions whenever the perceptual QPA is enabled for encoding. Given that the desired data for each CTU are already calculated inside the QPA method executed prior to the ALF encoder method, said values only need to be accessed by the affected ALF encoding routine, which does *not* increase the coding complexity or run-time. Bjøntegaard delta (BD) WPSNR statistics confirm the subjective benefit of the proposed correction to the VTM/BMS software.

It is suggested to adopt the proposed modification to the ALF encoder in the next version of the VTM/BMS software. Note that this change does *not* affect fixed QP coding as specified in the Common Test Conditions.

BD rate difference is very small (< 0.1%). Has some minor PSNR loss (0.2%) for LD configuration for class E.

Q: what about SAO? May not have the issue but should be confirmed.

Seems to be the logical thing to do.

Decision (SW): adopt.

[JVET-L0241](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4333) AHG10: Adaptive lambda ratio estimation for rate control in VVC [Z. Liu, Y. Li, Z. Chen (Wuhan Univ.), X. Li, S. Liu (Tencent)]

This contribution presents some improvements based on the current rate control scheme proposed in JVET-K0390. With the proposed adaptive lambda ratio estimation algorithm, when using the anchor bit rate of BMS2.1 with VTM configuration as the target, there are 0.34%/4.57%/4.09% for Y/U/V coding efficiency improvements in random access (RA) configuration reported when compared with the rate control algorithm in JVET-K0390.

Some loss is reported on class A1, up to about 1% for the Tango sequence.

Changes to the VTM software are about 10-20 lines of code.

No action. Further work on rate control was encouraged.

[JVET-L0610](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4723) Crosscheck of JVET-L0241 [J. Chen (Samsung)] [late]

# Metrics and evaluation criteria (2)

Contributions in this category were discussed Tuesday 9 Oct 1800–2000 (track A chaired by F. Bossen).

[JVET-L0167](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4258) AHG7: Subjective Quality Evaluation of VVC HDR sequences on UHD TV [A. DSouza (Samsung)]

Presenter not available at 19:53 on Tuesday Oct. 9.

Reviewed at 11 Oct 18:00, chaired by J. Boyce.

This information document presents a method to generate HDR/WCG sequences from VVC bitstreams, for viewing of HDR/WCG video on commercially available UHD TVs.

The contribution provides ffmpeg command line arguments. The method involves transcoding to the HEVC format with insertion of HDR related VUI and SEI messages.

[JVET-L0365](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4462) MS-SSIM as an additional metric [Y. Zhao, H. Yang, J. Chen (Huawei), M. Pettersson, R. Sjöberg, P. Wennersten (Ericsson)]

This contribution proposes to include the MS-SSIM metric as additional metric in VTM and make MS-SSIM Y mandatory in the CTC for SDR video. A patch for MS-SSIM integrated into VTM 2.0.1 and an updated excel template for the CTC for SDR video are provided. In terms of MS-SSIM Y, VTM2.0.1 achieves -16.28%, -22.86% and -17.47% BD-rate over HM16.18 in AI, RA and LB, respectively. In terms of PSNR Y, the BD-rates over HM16.18 are -18.03%, 23.08% and -18.29% in AI, RA and LB, respectively.

No test results were provided in the contribution. Some test results, e.g., VTM vs. HM were requested.

Revised version of contribution contains such results.

For most tools, BD-rate measurements using PSNR or MS-SSIM are very similar.

It was remarked that it may be preferable to have an external tool to measure MS-SSIM instead of integrating it into VTM as relying on encoder output is not ideal.

No experts present in the room (other than proponents) expressed intent to use such metric if made available in VTM.

No action.

No test results were provided in the contribution. Some test results, e.g., VTM vs. HM were requested.

# Plenary meetings, joint Meetings, BoG Reports, and Summary of Actions Taken

## Plenary meeting Sunday 7 Oct 0900

Reports of the tracks were given by GJS (track B) and JRO (track A) as follows (from the discussions, see also some comments added to the respective sessions)

Track B

* CE2 Adaptive loop filter and related
  + L0083 Reduced bit-depth coefficients (complexity reduction, no loss)
  + CE2.6.2 Subsampling of classifiers (complexity reduction, text in L0147, tiny loss)
  + L0392 Context initial states (minor correction, a tiny bit of gain)
  + Remove signalling of 5x5 as a special case for luma
* CE4 Inter prediction and related
  + Adopt 4.1.6.a Simplification on AMVP candidate list construction (complexity reduction, text in L0271, no loss)
  + Adopt 4.1.11.a (complexity reduction, line buffer reduction for affine inherited candidates, text in L0045, 0.1% loss)
  + Adopt 4.2.6.d affine merge as modified in L0632 (coding eff, pending adaptation of text, 0.66%)
  + Adopt 4.2.8 moving ATMVP into the affine merge list (cleanup, assuming ATMVP operates on a subblock basis, pending text, 0.03% penalty)
  + Adopt 4.4.12.a (0.38% in RA), merge with average of pari, list size 6 (text in L0090)
  + Merge with MVD variant b with base candidate from merge list (1.29% in RA)
  + History method with 6 candidates for merge list (0.58% in RA, text in L0266)
  + BoG reviewing related contributions
* CE9 Decoder motion vector derivation and related
  + L0256 BIO (1.28% in RA, text being prepared)
  + BoG to review non-CE contributions
* CE10 Multi-hypothesis and combined prediction
  + No action (yet)
* HLS
  + NAL units, SPSs, tiles, no CTU-level slices
  + PPSs or (perhaps repeatable) picture headers
  + Maximum capability negotiation header level – something with a persistence scope beyond the CVS
  + Tile groups, starting point with raster order (not presumptive status), flag after each tile to indicate whether there are more. Discussion in the plenary resulted in the following Decision:
    - CABAC stop bit at the end of each tile.
    - No flag to indicate the last CTU in tile.
    - Number of tiles minus 1 in header, entry point signalled for each tile
    - The syntax of the last tile is no different from any other tile, and there is no additional syntax after that tile in the NAL unit.
  + Design goal of extracting VCL NAL units of an MCTS and reposition to another bitstream without substantial difficulty
  + Some system interaction issues were identified that would require feedback from systems experts if action is to be taken on them.
* Other
  + Decision (CTC): Make Class F mandatory (but not included in the average).

Track A:

CE1: Partitioning

* Picture boundary handling – no action
* Split constraints – restrict “virtual data pipeline” to 64x64 – some loss, deemed useful, BoG
* Separate trees – signalling at CTU level or lower (intra / inter): Not enough benefit, except for “constructed sequences” – no action

CE3: Intra prediction and mode coding

* CE3.1: Multiple reference line prediction (9 tests) – adopt method that uses (with signalling) line 1 or 3 (within CTU only) – 0.4% gain, almost same encoding runtime
* CE3.2: Intra prediction modes (9 tests): Interesting gain from sub-partition (1%) and   
  (non-)linear weighted prediction (2.5%/1.6%), but encoder/decoder complexity concerns; multiple direct modes 0.2% gain, but more complexity in list construction
* CE3.3: Intra reference sample interpolation (7 tests): Promising gain (0.4%), complexity study of different proposals ongoing
* CE3.4: Bidirectional prediction (3 tests) – no action
* CE3.5: Cross-component prediction and separate chroma tree (18 tests): Adopt proposal using only 1 line at CTU boundary for CCLM; adopt new computation for linear model which is significantly less complex; adopt MDLM (switching left/top region), about 2% chroma gain; other methods non action or further study
* CE3.6: Intra mode coding (7 tests) – 6 MPM shown to have benefit – BoG about studying different proposal

CE5: Arithmetic coding engine

* Probability estimation with subtopics higher precision (lin vs. log), multi-probability models (add. 0.3%), customized estimation window (add. 0.3%), total around 1%. Complexity/pipeline throughput study of proposals in BoG
* Precision of engine itself

CE6: Transforms

* CE6-1: Primary transforms (21 tests, 11 proposals): Ideally, the transform should have the following properties:
  + - Sharing of as much as possible building blocks for different transform types and sizes
  + - Implementation either as matrix multiply or fast algorithm, independent of specification
  + - Implementation with 16-bit logic (at least for 10-bit video)
  + - As low complexity as possible
  + - Re-usability of legacy building blocks might be desirable
  + - Specification as matrix multiply, or cascade of matrix multiplies, or other e.g. butterfly
  + - Extraction of smaller transform sizes from largest size 64 (32 for MTS transforms)

No proposal solves all of these aspects. One proposal adopted which goes back to original HEVC DCT-2 transform (8-bit integer representation of matrix values, with 64-length transform added). Some of the MTS transforms (DCT-8/DST-7) more difficult to implement in fast algorithms due to asymmetry. Further analysis of proposal properties in BoG

* CE6-2: Secondary transform (6 tests, 2 proposals): Interesting reduction of complexity, only 4 transform sets, but results only available in combination with reduced version of MTS (which gives 1% in AI, 0.6% in RA with overall no increase in encoder/decoder time). Proponents requested to provide results of sec. transform itself on top of VTM, estimate it would be close to 2% rate gain in AI, close to 1% in RA.
* CE6-3: Transform combinations and signalling (7 tests, 3 proposals): Combinations of MST and NSST more of BMS style, no action here.

CE7: Quantization and coefficient coding

* CE 7.1: Transform coefficient coding (4 tests): Adopted new binarization for dependent quantization, 0.15% gain
* CE 7.2: Block adaptive quantization / residual coding (7 tests): Subjective quantization no specific action, some bit rate reduction for saving quantization parameter bits (but loss versus CTC)
* CE 7.3: Transform coefficient scanning (3 tests): No benefit

CE8: Current picture referencing: CPR (HEVC style) results with different restrictions of reference area. Restriction to current CTU (or current plus left) most promising in terms of memory (avoiding problem of storing entire picture in two versions). Gain around 40% for SCC class (less for class F), but only 0.2% for CTC. Another approach with decoder side template matching uses similar memory, but more complex decoder processing (though largely reduced relative to previous proposals), gives 1% for CTC, but less than CPR for SCC content. It is discussed in the plenary whether CPR with CTU restriction would be mature for VVC adoption. Since CTU is larger in VVC, necessary memory (cache?) could be of concern – could also have relation with the “virtual data pipeline” of CE1.

CE11: Deblocking

* Longer filters for large blocks: Various proposals, all add some processing complexity which may be of less concern for large blocks, but also more line buffer. Further analysis of subjective test results ongoing
* Various aspects: Adopted one proposal for brightness-adaptive strength adaptation (aleady in CfP, shown beneficial in subjective test); expression of adaptation variable, default none.
* Deblocking at 4x4 block boundaries: Seems useful as per subjective results, parallelism is possible from CE contributions, complexity analysis of details ongoing

CE12: Mapping functions: HDR – In-loop and out-of-loop reshaping seem almost identical in results (out-loop seems sufficient). For SDR, in-loop reshaping provides objective (BD) gain 1% for AI, 1.2% for RA. However, the method requires block-level reshaping and inverse reshaping in decoding process, and introduces additional inter-component dependency.

CE14: Post-reconstruction filters: Two approaches – bilinear and Hadamard-domain. Both are block-level building blocks, per se manageable in complexity, but could be critical in intra prediction (additional cycles between reconstruction and prediction. Both give 0.7% in RA, 0.5% in AI. More detailed complexity analyis (BoG), then decide.

CE15: Palette mode: Investigates palette (close to HEVC) in VTM, and another reduced complexity method. Only gives gain for screen content sequences, less than CPR (30% in SCC set), but additional gain (few percent) still are retained when combined with CPR. From the discussion in plenary: As palette mode is a completely different building block specifically beneficial, lower complexity solutions may be desirable. General aspect how to deal with tools that are specific for one type of content to be clarified.

CE1-related was discussed. Some straightforward cleanups and more flexible tree property signalling was agreed.

## Plenary Wednesday 10 October 1400

Track A

* Decision: Adopt JVET-L0053 first aspect / JVET-L0272. Proponents shall check if their text is identical and if not, unify them.
* Decision: Adopt JVET-L0279 CE3-related: Unification of angular intra prediction for square and non-square blocks
* Decision: Adopt JVET-L0095 CE6-related: Simplification on MTS kernel derivation
* Decision (BF/SW): Adopt JVET-L0111 CE6-related: Transform Skip Condition on Transform Block size
* Decision: Adopt JVET-L0628 3.1.4.2 CE3.3: Intra reference sample interpolation (as this filter is used somewhere else in the design)
* Decision (ed./text improvement): Adopt JVET-L0217 Non-CE1: Relation Between QT/BT/TT Split Constraint Syntax Elements (as per v4)
* Decision: Adopt JVET-L0361 CE1-related: Context modeling of CU split modes (version with 22 context models)
* Decision: Adopt JVET-L0678 QT/BT/TT Split Constraint Syntax Elements Signalling Method. The split constraints in CTC were not to be changed, but encoder needed to be modified to signal them.
* Decision: Adopt JVET-L0209 PCM mode with dual tree partition
* Decision: JVET-L0362 Quantization parameter signalling Adopt method 1 (depth is QT depth + BT depth)
* Decision: Adopt first aspect of JVET-L0428 Delta QP and Chroma QP Offset for Separate Tree (use centered position to fetch collocated luma QP).
* Decision (bug fix): JVET-L0553 Adopt second fix to semantics of init\_qp\_minus26 where +25 is changed to +37
* Decision (SW): adopt JVET-L0181 AHG10: Corrected operation of ALF encoding with perceptually optimized QP adaptation.
* Decision: Adopt JVET-L0165. Text was reviewed in BoG. It is however pointed out that there is an inconsistency in the specification of coding the remaining modes. The software codes them as truncated binary, whereas the text specifies fixed length coding (as was used with 3 MPM before). It was to be confirmed by text editors that the specification had been corrected.
* Decision from BoG on CE1 SubCE2 and related contributions Adopt JVET-L0081 Test 2.1.2

Track B

* JVET-L0043 Decisions on agreements in principle:
  + It was suggested to agree in principle, as a starting point, to have something at the start of the SPS that indicates properties that cannot be violated in the entire bitstream. Agreed.
  + It was suggested to start with presumption that there would be a list of disable flags. Agreed.
  + It was suggest to agree in principal that there would a separation between things that affect the syntax or decoding process and things that merely express constraints. Agreed.
* JVET-L0098 The decision was to disable the DMVR for the coding block sizes with either width of height of 128.
* JVET-L0691 BoG recommended adoptions to VTM
* Normative changes
  + Unification of affine CPMV, choose L0047 method 1 or L0047 method 2 (the same as L0373)
    - Method 1 control point MVs are stored and used only for model inheritance, other places (ATMVP storage, deblocking, motion comp, spatial neighbours for merge list, AMVP list derivation) use subblock MVs calculated from the control point MVs. This method has some extra memory (~768 bytes for hardware implementations) and a small benefit (0.05% average). It was commented that a new contribution L0666 reported that the peak loss for method 2 for some non-CTC affine-friendly sequences was substantially bigger. Method 2 is reportedly always (a little) worse in coding efficiency. Another late contribution reports a way to reduce the extra memory. If the subblock size is made bigger, method 2 would have some inconsistency in the motion vector field relative to the model. Decision (design cleanup): Adopt method 1 as the more consistent and “clean” design (roughly neutral on coding efficiency 0.01%). Further study of other schemes is anticipated.
  + ATMVP modification: use fixed subblock size 8x8 for ATMVP (L0198, L0468, L0104, possibly some others). Currently we’re adaptively using 4x4 or 8x8 subblock size, but this has no benefit. Decision: Agreed (approx. no coding efficiency impact).
    - In the plenary, it was noted that deblocking for ATMVP only applies to 8x8 CU boundaries, so the subblock boundaries are not deblocked. It was said that deblocking is applied to 8x8 boundaries for affine prediction, but another participant said this was not the case. It was noted that the residual transform is applied across subblock boundaries, and suggested that the deblocking should depend on whether there is a residual and perhaps whether it has non-DC coefficients. It was commented that CE11.3.2 proposed applying deblocking at ATMVP subblock boundaries.  
      It was agreed that we need to add text for deblocking into the draft text.  
      Decision: It was agreed that the draft spec will say deblocking is applied only at 8x8 grid-aligned TU boundaries and when there is no residual, deblocking is applied if there is a motion vector difference above the threshold on an 8x8 grid-aligned position. The software needs to be checked to ensure that this is what it is doing too. Further study of these interactions is needed. The deblocking BoG met later to address details.
  + ATMVP modification: restrict ATMVP mode to CUs of which both the width and height are larger than or equal to 8 (L0055), note that this is already a part of 4.2.8 which had been adopted. Decision: Agreed (approx. no coding efficiency impact).
  + ATMVP modification: check the first spatial neighbouring motion vector and use this as the reference motion vector for the collocated position for motion vector derivation (L0198). Decision (complexity reduction): Agreed (approx. no coding efficiency impact).
  + Reset the FIFO table in each CTU row for HMVP (L0106, L0158 method 1). Decision (complexity reduction): Agreed (approx. no coding efficiency impact).
  + Merge index coding: use one context for the first bin of the full-block merge index and bypass coding of other bins (L0194). After discussion, it was noted that this had not been tested for the subblock merge list and we don’t want different syntax for the two cases. Further study in a CE was planned to test doing the same thing for the subblock merge list. Decision (complexity reduction): Agreed (for the full-block merge index only at this time, approximately no coding efficiency impact).
  + Generalized bi-prediction (L0646). About 0.66% gain on RA, about 6% increase in encoding runtime. There was discussion of the alternative of using weighted prediction with multiple weights per picture. Weighted prediction would probably work better than this for fade-in, fade-out, and cross-fades (e.g., since it doesn’t need block-level weight selection and since it can extrapolate as well as interpolate), so this proposed method is not a complete replacement for weighted prediction. It was commented that there had been previous contributions describing a benefit for using weighted prediction with multiple weights, and there is some support in the JM for this sort of usage, but not in the HM. AVC had an extra, implicit mode of weighted prediction that was not adopted into HEVC, but it used POC weighting rather than signalling to establish the weights. A proponent noted that the syntax of weighted prediction does not have a shortcut for biprediction with two weights that add up to 1, so the proposed signalling of what is proposed as “generalized biprediction” for VVC would be more efficient when that constraint is intended to apply (e.g., the equivalent of selecting among 5 pairs of weights that add up to 1 would require selection among many more possibilities). Decision (coding efficiency): Adopt L0646 (0.66% coding efficiency; weighted prediction should also be put in the draft, but this and weighted prediction would be mutually exclusive at the picture level, when used with OBMC the weights of the neigbours would apply for the neighbour predictors, which is how the BMS software already does it, no consideration in deblocking filter). Further study of alternative approaches is expected and encouraged.
  + Prohibit 4x4 bi-prediction for inter CU (L0104 & L0371). Decision (complexity reduction): Agreed (negligible effect on coding efficiency). Further study is planned for other related aspects.
  + L0265 to set the chroma subblock size to 4x4 instead of 2x2 for affine motion compensation by averaging the MVs of the 4x4 luma subblocks. It was commented that SIMD implementation is feasible for 4x4 but not 2x2. This has a negligible coding efficiency effect. It was noted that we also have 4x4 ordinary CUs, so this doesn’t entirely solve the 2x2 problem, but would leave that as the only case where this occurs. This would apply to both uni an bi-prediction. Decision (complexity reduction): Adopt.
* Bugfix of VTM software
  + Align the software with the draft text regarding ATMVP motion vector clipping (L0257). Decision (change software to match text): Agreed.
  + Rounding motion vectors toward zero rather than toward minus infinity for AMVR (L0377). Decision (change software to match text): Agreed.
  + L0093 align VTM with draft text regarding the pruning of regular merge list (the same as L0282). The draft text does not do full pruning for the spatial and TMVP candidates in the merge list. The software does full pruning. It was reported that there is no loss for not doing full pruning. Decision (bug fix): Align software with text.
* Encoder optimization
  + Encoder optimization for affine motion estimation (L0260). Decision (software): Adopt (0.3% coding gain, 3% encoding time increase).
* L0694 interaction refinement (L0045 line buffering for affine model inheritance across CTU boundaries interaction with L0047 storage of subblock motion vectors). This was further discussed in the plenary, without change of the decision.
* Adopt CE10.1.1.c combined intra/inter with restriction to w×h >= 64 luma samples (0.5% in RA)
* Decision (coding efficiency): Adopt Non-rectangular (triangular) partitions (0.57% in RA, 1.23% in LB), with the L0208 bug fix, flag after combined intra/inter.

360° BoG report was reviewed

## Closing plenary sessions

## Joint meetings

## BoGs (XX)

In the track A meeting Mon. 8 Oct. 1400, the following BoGs were established:

1) BoG on Screen content tools (Y.-C. Sun, X. Xiu)

- to review the contributions from 7.8, 7.15, 7.17, and recommend items to be investigated in the upcoming CE8, CE15

– to assess memory requirements of current-CTU CPR

2) Merge the previous two BoGs on deblocking, and nominate A. Norkin, A. Segall, A. Kotra as chairs of that BoG, and extend the mandates to perform further analysis of CE11 contributions, also review the contributions from 7.11, and recommend items to be investigated in the upcoming CE11

[JVET-L0647](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4761) BoG report on 360º video [J. Boyce]

The BoG on 360° Video met on 5 Oct 2018 in two sessions, with informal subjective viewing conducted in between. The BoG also met on 7 Oct 2018. The BoG plans to meet again to discuss CE planning. The BoG recommended:

* JVET-L0231: adopt to the VTM, for horizontal geometric padding of inter-prediction references for ERP/PERP (and other single face projection variants)
  + Also update 360° CTC to enable in the PERP anchor.
  + In plenary, it was said that rather than involving a 360° format indication, this could just be a horizontal wrap-around flag with an offset of where to start the wrap-around. This was said to improve subjective quality for ERP/PERP projections, and provide some objective gain on some test sequence (esp. a moving camera with ERP). Decision: Confirmed (without projection type signalling – syntax and description not to imply a meaning).
* JVET-L0238: adopt the proposed changes to 360Lib and the 360° CTC to add support for different chroma types.
  + The 360Lib document should also describe this more clearly, as it will impact client-end operation. Decision (SW): Agreed.
  + Is there any effect on the HEVC SEI messages for cube map? This issue should be raised to JCT-VC and OMAF.

The BoG suggested:

* That VVC eventually include support for sub-CTU tile sizes, to allow more flexible alignment of tiles with cube faces, which could be used to disable in-loop filters at tile face row boundaries. (Not necessarily immediate action; see notes on HLS section.)
* Continue CE13, with same coordinators
* Discussion about whether 360º video specific tools can be included in a “Main” profile, or whether a “360” profile might be defined; e.g., for cubemap-based processing with face rotations. It was commented that the wrap-around seems not so difficult, but more specialized processing than than would be difficult to include in a “Main” profile. This should be further studied.

The BoG met further for CE planning.

[JVET-L0658](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4772) BoG report on CE1 SubCE2 and related contributions [C. Rosewarne, M. Zhou]

The BoG on CE1 SubCE2 and related contributions has mandates to review the following proposals: CE1 SubCE2 tests of CE1 (JVET-L0021) and related contributions (JVET-L0050, JVET-L0128, JVET-L0313, and JET-L0551).

The BoG met on Friday October 5th at 19:30 to 22:30.

It was suggested to firstly review JVET-K0566 to explain the asserted pipeline processing issues.

Prior to VTM-2.0, a ternary split at the top level of the coding tree resulted in a TU spanning the VPDU boundary (64x64 grid).

It was commented that one issue is to keep any CU within a VPDU size as a 1D buffer so CU size does not exceed 4096 luma samples, so that the buffer may be contained inside the buffer. If the CU is larger than this.

Another pipeline issue was to restrict the stride to not exceed 64, so maximum CU width is 64.

One comment was that each TU should be contained within 64x64 regions and should not cross such boundary. Also commented was that all processing of TUs in one 64x64 region should complete before progressing to the next (64x64) region. This restricts 32x128 CU is not possible due to top-level scan at 64x64 level.

It was questioned whether changing the stride (e.g. 32 for 32x128 CU) was a problem. Putting two 32x128 partitions together is still the same size as two 64x64. Depending on how samples are read from memory (e.g. 32x1) then the amount of accesses would only increase when the partition size became narrower than the width of samples read. Highly architecture-dependent how samples are fetched.

The method proposed two conditions: Firstly, that for VPDU containing multiple CUs, all CUs are fully contained within the VPDU. Secondly, that for CUs containing multiple VPDUs, the VPDUs are fully contained within the CU.

The more flexible processing order of CUs resulting from the tree structure increases complexity.

[JVET-L0021](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4561) CE1: Summary report on partitioning [J. Ma, F. Le Léannec, M. W. Park]

**SubCE2**

Test 2.1.2 implements, relative to VTM-2.0.1, the added restrictions are that a 128x64 cannot have binary H split and a 64x128 cannot have binary V split. A loss of 0.15% and 0.06% were seen in RA and LDB, respectively.

It was commented that the coding impact is resolution dependent, with higher resolutions having larger loss. For example, RA had 0.38% loss in class A2 (DaylightRoad having 0.65% loss).

This proposal addresses the TU location aspect and the CU processing order aspect.

[JVET-L0050](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4131) CE1-related: Split Constraint Considering Picture Boundary Condition [M. W. Park, M. Park, K. Choi (Samsung)]

This proposal is based on SubCE2.1.2. It was asserted that the picture boundary condition was not considered in the test.

The proponent of SubCE2.1.2 commented that their software included the ternary split bugfix (this was confirmed), and this is why a higher loss was seen.

An example is a picture boundary split resulting in a ‘left’ 32x128 CU can occur, which is goes against the processing order aspect. It was commented that since the ‘right’ 32x128 does not exist and so does not need to be re-entered, and so there is no processing order issue.

At the picture boundary, it was commented that there is no choice but to allow such 32x128 CU that would otherwise be considered a processing order issue. Moreover, the 32x128 CU can still be contained into the same buffer size as 64x64.

It was commented that the additional cost of the flexible processing order, e.g. regarding increased addressable cost, does not prohibit implementation.

In the primary proposed method, a 32x128 CU is not allowed to split into 16x128 CU but is instead allowed to split into two 32x64 CU, at the picture edge only (with similar example for the bottom boundary). So width <=64.

It was commented that the ternary split under this case (parallel to the edge of size 128) was not prohibited, as the basis software was VTM-2.0.1.

In addition to the primary method, an additional three methods were proposed on top of the primary method (the split constraint) but the proponent stated there was no need to present these three sub-methods.

The proposed method has 0.08% loss in RA vs 0.15% loss in Test 2.1.2, even though less split option was available. The maximum loss seen was for RA, class A2 had a loss of 0.17%, with the highest loss seen in DaylightRoad at 0.27%.

For test 2.1.2, encoder runtime 94% in RA and 98% in LDB, respectively. For this proposal encoder runtime of 98% for RA and 98% for LDB, respectively.

[JVET-L0128](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4209) CE1-related: Transform tiling for pipelined processing of large CUs [C. Rosewarne, A. Dorrell (Canon)]

VTM-2.0 introduced a constraint to prohibit performing a ternary split of a coding tree node with a side length exceeding 64. This restriction prevents any TU from spanning a 64x64 grid boundary (in luma, with corresponding constraint in chroma), which may be a unit of granularity for a pipelined architecture to process a frame. The current design performs a TU tiling operation for a CU larger than the available transform sizes. This contribution proposes to extend the tiling operation of TUs within a CU such that smaller TUs are used to prevent the resulting TUs from crossing the above-mentioned 64x64 grid boundary, instead of imposing the ternary split restriction. Coding results in RA are -0.17%, -0.14%, and -0.18% and LDB are -0.15%, -0.23%, and -0.18% in Y, Cb, and Cr channels, respectively.

In class A2, for RA a gain of -0.27 was seen, with -0.43% gain in DaylightRoad2.

The current TU tiling in VTM applies only to multiple of 64 TU, which uses DCT-2, but here smaller transforms may be used.

This proposal addresses the TU tiling aspect but does not consider the CU processing order aspect, which the proponents assert is a manageable cost.

[JVET-L0313](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4408) CE1-related: Non-square virtual pipeline data unit [M. Xu, X. Li, S. Liu (Tencent)]

Virtual pipeline data units (VPDUs) are defined in JVET-K0556 as non-overlapping MxM-luma(L)/NxN-chroma(C) units in a picture. In hardware decoders, successive VPDUs are processed by multiple pipeline stages at the same time; different stages process different VPDUs simultaneously. The VPDU size is roughly proportional to the buffer size in most pipeline stages. In this contribution, the VPDU is extended to cover non-square regions. It is reported that 0.00%, 0.22%, 0.14%, and 0.17% luma BD-rate reductions are achieved on average over BMS-2.1 with VTM configurations for AI, RA, LB, and LP configurations.

As background, different shape VPDU is allowed, provided the area is the same. Not only may VPDU be non-square but may also be irregular in shape. For example, a 128x128 CU with two ternary splits in opposing directions and finally a binary split in the centre introduces say two 32x64 CU in the centre. Two 32x128 VPDU exist for the side CUs of the CTU and two ‘L’ shaped VPDU process each process a 64x32 CU and a 32x64 CU. It means a centre 64x64 CU inside a CTU is not possible.

Results for RA in class A2 are -0.37% and overall was -0.22%. For DaylightRoad2, a gain of -0.59% was observed.

There is no TU or CU spanning a VDPU boundary, and VPDU processing order matches CU processing order.

It was commented that the addressing for the L shape is more complex, and that using a 128x128 buffer may be preferable. Reconstructing the L shape region back into square VPDU would require more buffering and delay.

It was commented that results with only square-shaped VPDU would be of interest.

Another comment made was that these constraints are affecting the more relevant operating points of the codec (UHD).

[JVET-L0551](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4660) CE1-related: fix on ternary split restriction [Y. Zhao, J. Chen (Huawei)] [late]

In VTM2.0, the maxTtSize is set as 64 to disabled TT splits for a 128x128 node. In VVC draft 2, if one side of a node is larger than maxTtSize, neither vertical nor horizontal TT split is allowed. In fact, an Nx128 (N<=64) node using vertical TT split does not cause one TU covering two 64x64 pipeline blocks, and is also allowed in VTM2.0.1. Therefore, the VVC draft 2 and the VTM 2.0.1 are not aligned. The previous adoption may not be clear enough on how to prohibit TT splits for Nx128 and 128xN nodes. This contribution proposes a description of TT split restriction. The coding results are identical to VTM anchor in VTM CTC.

Two issues for VVC: One is TU spanning two (64x64) VPDU. Other is processing order.

The VTM-2.0.1 does not disable the ternary split of a 64x128/128x64 block along the same direction as 128-length edge of the region. The text disallows such a split, even though such a split does not introduce a TU tiling issue.

This proposal suggests to align the VVC text with the VTM software, i.e. to allow the above split. As such, there is no coding impact. The coding result of implementing the restriction as made in Ljubljana was not provided.

It was commented that although there is no TU tiling issue in VTM-2.0.1 and hence in this proposal, the CU processing order does not follow 64x64 VPDU.

A software change was included which replaces the existing condition with a different one having the same effect, however one that allows MAX\_TT\_SIZE be set independently of the pipeline size.

The BoG had consensus that TUs should be contained within VPDUs. It was further commented that TU processing order should not result in later reprocessing an earlier VPDU. However, at the picture boundary the implicit split is not consistent with this constraint.

The BoG had consensus that CUs could cross the VPDU boundary (so no need to e.g. effectively reduce CTU size to 64x64).

The BoG considered that two viewpoints were in contention: 1. That flexible block structure should be retained in maximise coding efficiency at the higher resolution operating point, and 2. That constraints should be imposed that enable hardware pipeline designs at cost levels deemed acceptable.

It was commented that one solution that addressed the TU tiling and processing order constraints was the Test 2.1.2.

The BoG recommended further review in the main track.

From follow-up discussion in plenary: The problems to be addressed are

- which split constraints should be imposed in order to allow pipelining in 64x64 VPDU

- which scanning order of CUs would allow imposing as low amount of split constraints as possible

There is no common understanding whether some special handling (modified constraints) are necessary at picture boundary.

At the same time, the efficiency losses imposes by constraints should be as low as possible. The loss would be larger at high resolutions.

A possible solution would be to not only allow 64x64 units, but also 128x32 (as proposed in CE-related contribution L0313). There is however no consensus that this would be practical in hardware, it needs to be further studied.

It is agreed that test 2.1.2 which has been investigated in the CE fully solves the problem, although it has some compression loss (0.15% on average, larger on class A in RA). Continue CE testing the claimed advantages of JVET-L0313 and JVET-L0128 (which do not necessary comply to the current definition of VPDU as defined in JVET-K1021, but should have equivalent advantages in terms of memory usage addressing of memory and pipelining)

Actions decided in Track A (Tue morning)

Decision: Adopt JVET-L0081 Test 2.1.2

[JVET-L0662](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4776) BoG report on CE3.6: Intra mode coding [X. Zhao]

The BoG on CE3.6 and related contributions has mandates to review the following proposals: CE3 test 6.2.1 (JVET-L0165) and joint solution (JVET-L0222).

The BoG met on Saturday October 6th at 09:00 to 09:50.

Both JVET-L0165 (Test 6.2.1) and JVET-L0222 (Combo Test) are based on 6 MPM.

It is agreed to use 6MPM for intra mode coding, and intra mode coding scheme without parsing dependency is recommended.

The non-MPM coding is same between these two candidates, truncated binary code. There is difference between these two candidates regarding the 5th MPM candidate.

It was asked whether there is fast algorithm at the encoder side regarding the intra mode coding of JVET-L0222, and it was clarified by proponents that there are no increased RD checks, and there are actually no encoder modifications regarding the proposed intra mode coding scheme.

It was mentioned that there is optimization regarding the MPM derivation process in JVET-L0165: using Planar as initialization of MPM list which may provide additional benefit for the encoder.

It was commented that the positions of the neighbouring blocks are also modified in both two candidate solutions, and this individual aspect gives 0.07% gain (reported by CE related contribution JVET-L0154), while the total package gives 0.32% gain for the joint proposal (JVET-L0222) and 0.29% gain for JVET-L0165.

It was commented that JVET-L0222 may be not regarded as a CE test.

It is agreed that the joint proposal is a preferred solution for intra mode coding.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Max number of neighbours to access | Line buffer required? | Max layers of if conditions | Max number of comparison operator | Max number of logical operators | Max number of assignment operators | Max number of increments | Max number of bit operation | Parsing dependency? | Number of Context modeling for MPM coding | number of full RDO checks | Has LUT? | LUT size | Number of condition check for remaining modes | Non-MPM coding |
| 6.2.1 | 2 | N | 3 | 6 | 8 | 26 | 0 | 0 | N | 1 | 1 or 2 | N | - | 1 | TB |
| Combo | 2 | N | 3 | 8 | 5 | 27 | 4 | 0 | N | 1 | 1 or 2 | N | - | 1 | TB |

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|  |  | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Test#** | **Description** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 6.2.1 | Extended number of MPM rather than 3 | -0.29% | -0.24% | -0.21% | 100% | 100% | -0.11% | -0.05% | 0.01% | 100% | 100% |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Combined test of CE3.6** | | JVET-L0222 (Huawei, MediaTek, LGE, Qualcomm) | | | | | | | | | |
|  |  | **All Intra Main10 - Over VTM-2.0.1** | | | | | **Random Access Main10 - Over VTM-2.0.1** | | | | |
| **Test#** | **Description** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 6.1, 6.2, 6.3, 6.4, 6.5 | Combined proposal of CE3.6 | -0.32% | -0.26% | -0.24% | 101% | 99% | -0.13% | -0.09% | -0.09% | 101% | 101% |

[JVET-L0165](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4256) CE3-6.2.1: Extended MPM list [L. Li, J. Heo, J. Choi, J. Choi, S. Yoo, J. Lim (LGE)]

This contribution proposes an extended 6 MPM list with similar complexity compared to 3 MPM in VTM 2.0.1. In the proposed method, two neighbouring intra modes (left and above) are deployed for MPM list generation. Following the structure of the 3 MPM generation in VTM2.0.1, MPM lists are generated. The following three tests are performed in this investigation.

* CE3-6.2.1a: CE3-6.2.1 with CTU boundary restriction
* CE3-6.2.1b: CE3-6.2.1 without CTU boundary restriction

The experiment results reportedly show -0.29%, -0.11% and -0.33% and -0.13% bit rate changes for VTM-AI, VTM-RA for CE3-6.2.1a, and VTM-AI and VTM-RA for CE3-6.2.1b, respectively.

In the presentation of the BoG report in track A, concern was raised about the agreement. In particular, several experts said that there was not enough time to study the combined proposal thoroughly enough to understand if there may be throughput problems.

The gain of 0.3% is relatively low, and 6 MPM clearly has additional complexity compared to 3 MPM. Nevertheless, at least the proposal in L0165 is understood well enough that it does not cause implementation problems. In terms of performance, the difference between the two proposals is minor.

Decision: Adopt JVET-L0165. Text was reviewed in BoG. It is however pointed out that there is an inconsistency in the specification of coding the remaining modes. The software codes them as truncated binary, whereas the text specifies fixed length coding (as was used with 3 MPM before). Revised text was produced. It is to be confirmed that the specification is corrected. Corrected text was provided in a revision of L0165, and was reported to have seemed adequate to B. Bross.

Further discused 11 Oct 2018 1800 (Chaired by J. Boyce): An updated version of the document with revised specification text has been uploaded. Waiting for review by B. Bross.

[JVET-L0222](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4313) CE3 6.6.1: A simple 6-MPM list construction with truncated binary coding for non-MPM signalling [A.M. Kotra, B. Wang, S. Esenlik, H. Gao, J. Chen (Huawei), M. G. Sarwer, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek), L. Li, J. Heo, J. Choi, S. Yoo, J. Lim (LGE), A.K. Ramasubramonian, G. Van der Auwera, M. Karczewicz (Qualcomm)]

This contribution proposes a 6 most probable modes (MPM) based intra mode coding method. The MPM list is generated based on the left and top neighbouring modes. The truncated binary coding is used to signal the remaining 61 non-MPM modes. It is reported that under All Intra configuration this proposal can achieve −0.32%/−0.26%/−0.24% Y/U/V BD-rate for VTM2.0.

[JVET-L0681](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4795) BoG report on CE11: Deblocking filter [A. Norkin, A. Segall, A. M. Kotra (Huawei)]

This is a report of the Breakout Group on Deblocking that met during the 12th meeting. The Breakout Group was originally created as two Breakout Groups. The first on Long Tap Deblocking Filters, and the second on Deblocking for 4 x N and N x 4 block boundaries. Each of these BoGs met separately on October 7th, and then were combined on October 8th. The goal of the combined group was as follows:

* Long Tap Deblocking
  + Further analyze the results of subjective test in L0611
  + Identify whether it is possible to conclude that visual improvement over VTM (ALF off) has been achieved
  + Identify whether there is consistency that certain proposals perform better
* Deblocking for 4×N and N×4 block boundaries
  + Further analyze the proposals on 4x4 grid deblocking in terms of complexity (including decision mechanisms which block boundaries can be deblocked such that parallel processing is still possible)
  + Investigate possible interaction with CE11.2.2
* Perform additional expert viewing if necessary
* Review CE related documents on deblocking filters
* Recommend items to be investigated in the upcoming CE11
* Additional topic added after first version: Recommend whether or not apply deblocking on sub-block boundaries in ATMVP and affine motion.

The BoG met on October 7th from 6:15PM to 9:30 PM, October 8th from 6:30PM to 9:55PM, and October 9th 3:00PM to 7:00PM, October 10th from 4:20 pm to 6:30 pm, and October 11th from 9:30 am to 12:30 pm.

A first report of the BoG was given in track A Wed. 10 Oct. 1100.

A general discussion of subjective testing for long tap deblocking was conducted on October 7th. The notes from the discussion were:

It was commented that it may be beneficial to categorize the proposals that only modified the luma deblocking filters and those that modified both the luma and chroma deblocking filters.

It was commented that CE11.1.4 is operating on a 4x4 grid while other CE11.1.\* proposals maybe operating on an 8x8 grid. It was confirmed that CE11.1.4 is operating on a 4x4 grid by the cross checker.

It was commented that whether a long tap deblocking proposal operated on luma or luma and chroma is in the CE 11 summary report.

It was commented that some proposals only applied long deblocking when the width and height of a block was large, while other proposals applied long deblock filters when only the width (or height) was large.

It was commented that some proposals incorporated a decision to select long deblocking as an extension of the strong deblocking decision, while others always apply long deblocking for large blocks.

It was commented that some proposals used symmetrical filtering while other used asymmetrical filtering.

It was commented that some proposals did not extend the number of line buffers required to deblock the CTU boundary. At least one participant expressed that this was a desirable aspect.

It was commented by a participant that long tap filters appear to provide a visual benefit compared to the anchor based on the subjective results provided by the Test Chair.

Following the discussion, two presentations were made reporting analysis of the subject test results.

In a first presentation, one participant reported their analysis of the subjective results and asserted that it appeared that there were 8 cases where long tap deblocking had outperformed the anchor.

In a second presentation, one participant reported a second analysis of the subject test results. It was reported that the tests was conducted in two sessions, where each session consisted of a separate set of responses.

One participant observed that there may be some differences between the data in the two test sessions. It was suggested to consult the Test Chair to better understand.

One participant commented that it was challenging to observe differences between technologies in the ParkRunning sequence in evaluation in their lab.

It was communicated by the JVET test chair that only Campfire sequence should be used for drawing conclusions since this was one sequence that behaved consistently in the test JVET-L0611.

It was found that at least one long-tap deblocking filter proposal had non-overlapping confidence interval with the Anchor NoALF on the Campfire sequence. Another proposal had 1% overlap with the anchor, and one other proposal was rather close.

Some participants expressed opinion that we have evidence of the improvement over the VTM noALF anchor with long tap deblocking filters.

One participant expressed concerns that the conclusion was drawn based on one sequence.

It was recommended by the BoG to have a screening of a selected set of the CE11.1 proposals and the anchor to confirm that there is a subjective improvement from using long tap deblocking filters. The screening should be open to non-proponents and announced.

The group agreed that the selection below did not infer a recommendation to study the selected proposals in the CE or adopt any of them and should not be used to endorse proposals that were selected.

The visual demo of the proposals has been performed October 9, 12:00pm. The sequences were played in the order indicated below, and the comment from the participants were collected:

Campfire QP39:

AnchorNoALF

CE11.1.2

CE11.1.8

CE11.1.9

CE11.1.1

CE11.1.10

Comments: One participant says difference is small. Two participants see improvements in the fire and on the flag. Less fluctuation in the bottom of the picture for proposals compared to the anchor. One other proponent sees improvements in the subjective quality.

FoodMarket QP39

AnchorNoALF

CE11.1.5

CE11.1.8

CE11.1.9

CE11.1.1

CE11.1.10

Comments: Smoke in the beginning has less blocking artifacts with proposals. There was a comment that fade-in fade-out sequences may be used for blocking. Participant sees improvement in the smoke.

The discussion of the demo happened on Tuesday October 9, at 3pm.

It was asserted by one participant that some non-normative methods may help reducing large block artifacts and such methods can also be investigated in the next round of the CE.

Conclusion of the discussion:

* There is evidence that a problem with blocking artifacts in large blocks exists at higher QPs in VTM2.0.1.
* The BoG agrees that there is evidence that long-tap deblocking reduces large block artifacts on some content.
* Based on the available data, BoG could not determine which of the long-tap deblocking proposals performed more consistently than the other.

Recommendation: investigate the CE11.1 proposals in the next round of the CE.

The main mandate here was to cross verify the subjective results of CE 11.3 presented in the proposal [JVET-L0611](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4724). It was recommended by the Chair to perform an expert subjective test during the Macao meeting to cross verify the subjective results.

Due to the lack of resources, an expert subjective viewing could not be performed during the meeting. Instead an informal demo of all the CE 11.3 sequences which were submitted to the offline subjective test was conducted by the test chair.

The informal demo was conducted by showing the sequences in the following order:

* Anchor\_NoALF
* Anchor\_ALF

Then the sequences were displayed with ascending MOS scores for each sequence. The following proposals were shown in that order:

* CE 11\_3\_1\_NoALF
* CE 11\_3\_3\_S1\_NoALF
* CE 11\_3\_3\_S2\_NoALF
* CE 11\_3\_4\_NoALF
* CE 11\_3\_5\_NoALF

The following comments expressed by the experts in the BoG who attended the informal subjective demo:

One expert commented that for RA sequences, there was no subjective evidence observed. It was suggested that large blocks may mask the need for deblocking on 4 x N and N x 4 block boundaries.

One participant observed subjective quality improvement around object boundaries for KristenAndSara sequence in LD configuration when compared to the NO\_ALF Anchor.

One more participant observed no subjective evidence.

One participant commented that 4 x N and N x 4 blocks may not always happen but seem to appear sporadically and might be annoying if not deblocked.

One participant commented that the QP value used for 4 x N and N x4 deblocking should be determined, generally the higher the QP, the more chances that 4 x N and N x 4 blocks occur.

One participant commented we should first fix 4 x N and N x 4 blocks and then take care of longer tap filter.

One participant commented that the sub-block boundaries on 8 x 8 grid should also be deblocked.

A comment from participant was the group should determine a priority order of fixing types of deblocking artifacts and that it should be the following order:

* Longer tap
* Sub-PU
* 4 x 4 grid deblocking and parallel deblocking for 4 x N and N x 4 boundaries.

Further testing will be done in a CE to conclude if there is a definite subjective evidence for deblocking on 4 x 4 grids. One more subjective test demo is planned to be conducted with some non-proponents as test viewers

The second viewing session of the 4x4 filtering grid proposals was been conducted on October 9, 2018, at 12pm. Sequences KristenAndSaraQP34 and Kimono were shown with the proposals listed above. The following comments were collected.

For KristenAndSara, QP34

One participant thought that some proposals were worse than anchor. One proponent saw improvements (smaller blocks). Two participants saw differences but were not sure what was better. A proponent saw improvements along object boundaries.

For Kimono, QP34

Kimono was more difficult to assess. Some participants saw difference in the face but were not sure which variant was better.

The discussion of the demo happened on Tuesday October 9, at 3pm.

BoG agree there is less difference was seen on deblocking for 4x4 than on long-tap deblocking. Some participants are convinced that non-deblocked boundaries may happen, and the CE may need to define separate test conditions for 4x4 deblocking during the editing period of the CE (so far same test conditions as for the long-tab deblocking have been used). As an example block boundaries of 4x64 for inter-slices and 32x4 for intra slice, where these boundaries may not be deblocked.

Recommendation: investigating deblocking on 4x4 boundaries in the next round of the CE.

Possible interaction of deblocking on 4x4 grid with CE11.2.2.:

The BoG agrees that there is no interaction between CE11.2.2 and proposals that suggest deblocking on the 4x4 grid.

The above recommendations of the BoG were confirmed in track A (chaired by JRO Wed. 10, 1100)

From further discussion in track A:

* Identify most promising proposals to reduce number of tests
* Clarify with Vittorio how to arrange the experts viewing at next meeting; due to other activities in MPEG, it may be necessary that two viewing rooms are arranged, equipment is duplicated. It should not be a problem if some JVET experts run the tests with advice by Vittorio.
* Tests for the different sub-CEs should be separated, such that the effects of 4x4 deblocking, long filters, chroma, etc. can be judged separately (unless they are directly connected, e.g. when modified chroma and long filters are always used in combination
* To draw useful conclusions, number of proposals investigated should be kept low. Participants should not submit the same method with different configuration settings, but better judge beforehand what they themselves believe to be the best.
* From some observations, it could be that 4x4 block boundary deblocking is not so important for UHD content. The more critical issue might be that in VVC a larger block is not deblocked when its boundary is not at a modulo-8 position.

The BoG performed further analysis of CE11 proposals as follows:

* Luma deblocking complexity in *CE11.3*, deblocking on 4x4 grid

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Tests** | **Samples from block bound. modified** | **Samples from block bound. for deblocking decision** | **Max num. oper for filtering per line (add/mult/compar/shift)** | **Max number of oper. for decision for 8-sample boundary (add/mult/compar/shift)** | **Num. line buffers** | **Number of checks to determine block size** |
| CE11.3.1 | 2+1/1+2/1+1 | 3 + 3 | 1+1 weak filter of VTM (worst case 4 on both sides):  15 (6,2,6,1)  2+1 weak filter of VTM (>4 on one side and 4 on the other side):  22 (11,2,6,3) | (11/0/1/4) for “d” decision  “d” decision  Total 8 lines = 16 \*2 = 32 | VTM | 3 |
| CE11.3.3 S1 | 3+1/1+3/1+1 | 3 + 3 | (19/1/0/11)  3+ 1 with VTM strong filter | (11/0/1/4) for “d” decision  +  (8/1/3/4) for strong filter  Total 8 lines = 32\*4 = 128 | VTM | 2 |
| CE11.3.3 S2 | 1+1 | 3+3 | (4/3/1/1)  1+1 weak filter of VTM | (11/0/1/4) for “d” decision  +  + (4/3/1/1) for one sample / no filtering decision  Total = 16 \*4 + (9\*8)= 176 | VTM | 2 |
| CE11.3.4 | 2+2/1+1 | 3+3 (padding for outermost sample) | (16/1/8/7)  2+2 with VTM strong filter | (7/0/1/0) for d” decision  +  (8/1/3/4) for strong filter  Total 8 lines = 24\*4 = 96 | VTM | 2 |
| CE11.3.5 | 0 | 0 | 0 | 0 | VTM | 1 |
| JVET-L0614 Test1 | 2+1/1+2/1+1/3+1/1+3 | 3+3 (padding for outermost sample) | (19/1/0/11)  3+1 with VTM strong filter | (11/0/1/4) for “d” decision  +  (8/1/3/4) for strong filter  Total 8 lines = 32\*4 = 128 | VTM | 2 |
| JVET-L0614 Test2 | 2+1/1+2/1+1/2+2/3+2/2+3 | 3+3 (padding for outermost sample) | (21/2/10/9)  3+2 with VTM strong filter | (7/0/1/0) for d” decision  +  (8/1/3/4) for strong filter  Total 8 lines = 24\*4 = 96 | VTM | 2 |

In the worst case for filtering for two 4x4 adjacent blocks, if strong filter is applied, it can change upto 3 samples maximum on either side of the edge. This would have more operations when compared to CE 11.3.1.

11.3.5 does not perform any deblocking for 4x N and N x 4 blocks and therefore has less complexity when compared to applying strong filter for two 4 x4 adjacent blocks.

* Chroma deblocking complexity (*CE11.3*)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Tests** | **Samples from block bound. modified** | **Samples from block bound. for deblocking decision** | **Max num. oper for filtering per line (add/mult/compar/shift)** | **Max number of oper. for decision for 8-sample boundary (add/mult/compar/shift)** | **Num. line buffers** | **Number of checks to determine block size** |
| CE11.3.1 | VTM | VTM | VTM | VTM | VTM |  |
| CE11.3.3 S1 | VTM | VTM | VTM | VTM | VTM |  |
| CE11.3.3 S2 | VTM | VTM | VTM | VTM | VTM |  |
| CE11.3.4 | VTM | VTM | VTM | VTM | VTM |  |
| CE11.3.5 | 0 | 0 | 0 | 0 | VTM | 1 |
| JVET-L0614 Test1 | VTM | VTM | VTM | VTM | VTM |  |
| JVET-L0614 Test2 | VTM | VTM | VTM | VTM | VTM |  |

* Parallel processing (*CE11.3*)

|  |  |
| --- | --- |
| **Tests** | **Min unit size in luma samples that can be processed separately** |
| CE11.3.1 | 4x4 grid |
| CE11.3.3 S1 | 4x4 grid |
| CE11.3.3 S2 | 4x4 grid |
| CE11.3.4 | 4x4 grid |
| CE11.3.5 | 4x4 grid |
| JVET-L0614 Test1 | 4x4 grid |
| JVET-L0614 Test2 | 4x4 grid |

The BoG also made an initial proposal on candidate technologies for the upcoming CE. Some principles were discussed as follows:

* It was agreed that we need to reduce the number of technologies tested in the CE since there is high cost for subjectively evaluating them and it makes the subjective testing difficult.
* One proponent suggested to have a screening of the proposals during this meeting to determine which proposals seem more promising.
* One proponent suggested to limit a number of variants of proposals from one company, and a number of combinations (e.g. one proposal addressing one particular aspect).
* Promising technologies can be identified separately for each area (long filter, 4x4 deblocking).
* If visual screening occurs, the proponents are encouraged to submit the most promising variant for visual screening.
* One participant suggested that smaller number of line buffers between the horizontal CTU boundaries are encouraged (smaller line buffers). It was also suggested to use adaptive QP in subjective testing in the next round of the CE.
* It was agreed to contact Vittorio regarding pre-screening of the CE11.1 (long tap deblocking) proposals for participation in the next round of the CE (and discussing how such pre-screening can be done).
* Another proponent commented that side discussions among participants regarding voluntary reducing of number of proposals in sub-CEs (to provide a voluntary alternative to trimming number of proposals in the CE).

During discussion in track A, some concern was expressed against the “screening” method to reduce the number of proposals – this way, accidentally proposals that might have beneficial aspects could be excluded. Except the measure of enforcing only one submission per proposal, another approach could be to make a preselection in a first round of expert viewing, and more tests with a larger set of test cases and less proposals in a second round. It could also be viable to take only one proposal of two that are basically doing the same. If a combination is proposed, the two original proposals that were combined should not be subjectively tested.

Investigate whether a kind of preselection could be done ahead of the meeting.

The following recommendations were made by the BoG:

* Continue CE11
  + Continue CE11.1 long-tap deblocking filtering
  + Continue CE11.3 filtering on 4x4 grid
  + Continue remaining items in CE11.2 on general aspects
  + Consider CE related proposals in new round of the CE (listed in 4.1-4.3)
  + Reduce number of tests in CE11
  + Choose separate set of sequences and QP for subjective test in CE11.3
* Adopt JVET-L0410 (tC table fix) to VVC

The reviews and assessment of CE11 related proposals was confirmed by track A Wed. 10 Oct. 1230. The Recommendations were also agreed.

It was also mentioned that in CE4 a proposal was made related to deblocking of subblock boundaries. This should be studied in CE11 as well. See further notes under JVET-L0691.

Next round of CE was then further discussed in BoG.

After the initial review, the BoG met further October 10th from 4:20 pm to 6:30 pm, and October 11th from 9:30 pm to 12:30 pm.

Discussion of the outcome was held in JVET 11 October 1445 (GJS).

Outcome from the plenary: do deblocking on TU boundaries, if there are no transform coefficients, the PU boundaries are studied and MV differences are studied.

It was commented that we should unify deblocking behavior for ATMVP blocks and affine blocks.

It was also commented that currently affine sub-blocks boundaries do not have deblocking. It was also commented that there is no need to unify the approaches across ATMVP and affine.

A document L0074 was presented. The document asserts that currently deblocking is not applied to block boundaries in ATMVP. Currently, VVC deblocking is done on CU boundaries and TU boundaries.

PU and TU boundaries coincide with CU boundaries except the largest CU (128x128).

The block is split 128x128 CU into four TU, transform boundaries are filtered.

In all cases except ATMVP and affine, PU boundaries coincide with CU boundaries.

In HEVC deblocking, the boundary to be deblocked could be a CU, TU, PU boundary.

In was commented that in affine, block sizes are small – 4x4 blocks and residual is also likely. No known block artefacts were reported regarding blockingness on affine sub block boundaries.

For ATMVP:

It was commented that for larger block sizes (128x64) there will be deblocking on 128x64 blocks but it may not cover all block boundaries. One case where the problem allegedly may occur is 128x56 blocks.

One participant proposed to enable deblocking on 8x8 grid and inside a CU if the CU has ATMVP.

It was commented that the HEVC deblocking applies filtering in the following cases:

If the edge is a transform block edge and there are coefficients in either block.

If there are no transform coefficients or block boundary is not a transform block boundary then motion conditions are checked (i.e. the difference between motion vectors and reference pictures).

It was commented that HEVC definitions can be taken into VVC. The only thing that needs to be defined is the analogue of “HEVC PU boundaries” in VVC.

Recommendation: Apply the same logic to VVC (both ATMVP and affine) sub-blocks (on 8x8 grid) as to PU in HEVC deblocking. This means check the deblocking motion conditions for ATMVP and affine motion sub-block boundaries as if they were PUs in HEVC.

The text provided by B. Bross was reviewed by the BoG on Oct 11, 2018 (9:30 am). The BoG recommended to use this text in the current version of the VVC deblocking. K. Andersson volunteered to provide a software implementation to match the text. A.M Kotra volunteered to cross-check.

Decision: The recommendation of the BoG was agreed in JVET. For CE work on any other subblock-base modes (planar MV mode and others if any), the same scheme should apply (at least as an anchor).

*Proposals to test in CE11 and CE11 test conditions*

Discussion was held on Oct 11, 2018 9:30 am.

The BoG agreed on the following rule for testing proposals in CE11, to avoid needing to test too many combinations: If two (or more) proponents decide to submit a combination of their technologies (or aspects of the technologies) to CE11, they should withdraw their individual proposals from the CE. The decision of whether to go with the combination or with their original proposals should be taken by the proponents before the CE description finalization deadline.

The specific planned tests were recorded in the BoG report.

It was discussed whether and what optimizations are allowed when reporting complexity numbers in CE11 and to what extent. It was agreed to ask for guidance from the plenary regarding what optimizations are allowed when complexity numbers are reported, e.g. reporting always the best numbers, reference software implementations or best numbers for hardware or software. One suggestion was to report the numbers for the best implementation known and the other was to report the numbers according to how the scheme was implemented in the reference software. It was agreed to have both reported.

It was noted that having additional test equipment available and a second viewing room at the Marrakech meeting may be needed to enable on-site expert viewing tests. Subjective testing in advance of the meeting may also be possible, but will have some cost. Sponsorship would be needed for that (about 20 EUR per test point).

[JVET-L0684](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4798) BoG report on CE14 and CE14 related contributions [L. Zhang]

Complexity analysis of CE14.1.a and CE14.3.b

This section provides the data for different complexity aspects for the two selected CE14 test sets. Table 1 shows which blocks sizes that post-reconstruction filters could be enabled or disabled. Table 2 tabulates the complexity part for the two CE14 proposals based on CE14 descriptions while Table 3 shows the additional data for complexity comparisons.

Enabling and Disabling Post-Reconstruction Filters

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| CE14.1.a  CE14.3.b | 4x4 | 4x8 | 8x4 | 8x8 | 4xN or Nx4 (N>8) | 8xN or Nx8  (N>8) | 16xN or Nx16  (N>8) | 32xN or Nx32  (N>8) | 64xN or Nx64  (N>8) |
| intra | - | X | X | X | X | X | X | X | X |
| inter | - | X | X | X | X | X | X | - | - |

Complexity analysis according to CE14 descriptions

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Test | filter shape | Comp. complex. per sample\* | Precis. of mult | Parallel friendly | Latency for filtering process  (in clock cycles) | Latency for buffering | Memory required  (bytes) | How to derive filter coeffs | Min. and max. filtered  CU size |
| 14.1.a | 5 pixel “plus”-shape;  For inter, 5x5 area is used to calculate filter weights. | Current software implementation:  Intra:  4 mult 9 adds 4 checks  Inter:  4 mult 23 adds 10 checks  Maximum hardware parallelism:  Inter  6 mult 36 adds 20 checks | Intra:  9×8 and 12×9  Inter:  9×8 and 12×11 | yes | 3 | X | 63 | Intra:  Inter: | Min:  4x8, 8x4  Max:  Intra: 64x64  Inter: 16x64, 64x16 |
| 14.3.b | 3x3 | 0 mult 20 adds + 4 1-bit add for rounding 6 checks | n/a | yes | 2 | X | 70  (16 7-bit values per CU  ) | Pre-calculated in LUT | same as above |

Additional Information on Complexity Analysis

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | possibility that a different LUT may need to be used for the Hadamard filter for each next CU if the QP is switched to a different range. | SIMD complexity | Wo/ SIMD complexity | Operations before filtering | Sequential operation | Number of LUTs/Weights calculations per sample |
| CE14.3.b | 16\*7bits per CU | 104% for AI, 101% for RA  (from JVET-L326, pending cross-check) | 110%, 104% and 104%  for AI, RA, LDB |  | 5 add;  1 look-up table (14 bytes);  2 check | 3 table look-ups per sample |
| CE14.1.a |  | 102% for AI,  100.3% for RA  (from JVET-L0067, pending cross-check) | 105%, 102%, 103%  for AI, RA and LDB | 1 parameter with 9 bit , 1 mult and 1 add per CU before filtering | For intra:  2 mult, 6 add and 2 checks;  For inter: 2 mult, 12 add and 2 checks  (or 2 mult, 8 add and 2 checks with maximum hardware parallelism) | 2 weight calculations per sample |

Comments from hardware experts

* It is agreed that there should be no post-reconstruction filter for 4x4 intra and inter.
* One expert commented that no post-reconstruction filter for 4x8 and 8x4 intra and inter blocks is preferred (as neighbour could be intra, this also affects the intra pipeline). Gain would reduce to 0.52% for Hadamard, 0.58% for bilateral.
* One expert commented that no post-reconstruction filter for intra blocks should be used. (which would reduce the compression benefit to 0.45% in bilateral, 0.4% in Hadamard in RA) – concluded in track A that this would not be desirable
* Two hardware experts mentioned that CE14.3.b requires smaller chip size area compared to CE14.1.a

In the discussion in the JVET plenary, it is mentioned that the reported results of encoding/decoding time may differ in terms that one of them includes yuv output, the other not. When this is corrected, the Hadamard based approach is still slower (relative increase 1.5x) compared to the bilateral filter. This may be due to the LUT usage, which is costing more time in software.

Both methods are almost equal in terms of performance, whereas implementation-wise the bilateral filter appears to be favorable for software, the Hadamard-domain filter simpler for hardware.

Both are additional building blocks, such that the gain they give should justify the implementation cost.

It is expressed that practical encoders might not use this, as when enabled, the RD decision requires inverse transform at the encoder side. On the other hand, more elaborate encoders might use it. An encoder can disable it with high-level signalling, as there is no block-level signalling.

The additional cost of decoder implementation may be more critical for hardware.

CE14 related contributions reviewed in BoG:

[JVET-L0049](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4130) AHG16: An architecture study of bilateral filters [Y. Hu, M. Zhou (Broadcom)]

Suggestions from the proponent: if bilateral filter is applied, it is suggested bilateral filter is only applied

to inter-coded blocks.

Q: have you studied the new CE14.1 results?

A: CE14.1.a could fit 3 cycles latency for the filtering process. Latency for sliding window and buffering size depend on block size.

Q: How about CE14.3.b?

A: Other hardware experts commented that for CE14.3.b, 2 cycles latency for the filtering process is safe. 1 cycle latency for the filtering process is impossible.

[JVET-L0584](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4695) CE14.2-related: Extended applicability of bilateral filter (CE14.2.c) [D. Rusanovskyy, N. Shlyakhov, M. Karczewicz (Qualcomm)]

It was covered in the CE14 summary report. No need to be presented.

[JVET-L0615](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4728) CE14-related: Inter-only bilateral filtering [J. Ström, P.Wennersten, J. Enhorn, D. Liu, K. Andersson, R. Sjöberg] [late]

This contribution describes a variant of CE14.1a from JVET-L0172, where bilateral filtering has been turned off for all intra blocks. The BD-rate figures for an implementation in BMS-2.0.1 running in VTM configuration are reported to be -0.45% / -0.57% for RA/LD respectively.

It is claimed by the proponent of CE14.1.a that if CE14.3.b is only applied to inter coded blocks, the coding gain is -0.40% for RA. Confirmed by proponents of CE14.3.b.

Cross-checker reported that performance for low resolution is confirmed.

[JVET-L0656](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4770) CE14.3-related: Hadamard transform domain filter with modified LUT [S. Ikonin, V. Stepin, D. Kuryshev, A. Karabutov, J. Chen (Huawei)] [late]

This document is addressing to topic described in document JVET-L0636 CE14: Crosscheck of CE14.3 (JVET-L326) [1]. Detailed problem analysis is provided and solution is proposed. Proposed solution does not increase LUT size and provides additional BD-rate gain improvements up to -0.71% for RA configuration.

Compared to the CE14.3.c, the threshold where switches from using the LUT to using has been moved from 123 to 239.

The cross-check report in JVET-L0636\_r2 mentioned that

1. The modification solves the quantization issue with respect to a ramp of slope 61.5, but that is unsurprising: Since the discontinuity has moved from 123 to 239, the new ramp with artifacts is going to be for a slope 239/2 = 119.5.
2. The discontinuity due to subsampled LUT will cause quantization effects in the filtered output, especially for HDR sequences.

Simulation results show that there is no coding loss for JVET-L0656.

No one has reported whether there is subjective issue for SDR sequences and for HDR sequences, no one has checked yet.

[JVET-L0677](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4791)CE14 related: Decoder run time analysis non-SIMD and SIMD

This proposal compares decoder run times for AI for CE14.1a and CE14.3b for both non-SIMD and SIMD implementations. It is stated that non-SIMD run times are 105% for CE14.1a and 110% for CE14.3b. It is further stated that SIMD run times are 102% for CE14.1a and 106% for CE14.3b. Later, CE14.b has updated their AI decoder run time to 104%. The authors claim that the difference in SIMD run times is a factor of 2.

Conclusions

It is agreed that:

* If any tool from CE14 is adopted, the proponents are requested to provide data for subjective viewing to check whether there are artifacts due to the adopted technology.
* If there is another round of CE, cross-checkers are requested to launch subjective viewing tests on SDR and HDR sequences.

Overall conclusion after extensive discussion in track A:

Both methods are too costly in implementation to justify the gain.

No action. No continuation of CE.

[JVET-L0685](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4799) BoG report on CE6.1: Primary transform and related contributions [X. Zhao]

This BoG on CE6.1 is mandated to review the following three primary transform designs studied in CE6.1, and related contributions:

- COT with fast implementation similar to 6.1.4 (CE6-1.7g + CE6-1.4a)

- Aligning of MTS with DCT-2 basis (per 6.1.7a) with fast implementation (CE6-1.7a)

- Adjustment preprocessing of 6.1.6 (CE6-1.6)

Analysis of complexity, number of cycles to compute inverse transform, necessary bit depth of implementation stages is provided (confirmed by proponents). Comparisons versus complexity of fast implementations of DCT-2 are also provided.

The BoG met on Saturday October 7th at 18:20 to 22:20.

Three primary transform designs proposed in CE6.1 that are considered as interesting candidates:

- C1: COT with fast implementation similar to 6.1.4 (CE6-1.7g + CE6-1.4a)

- C2: Aligning of MTS with DCT-2 basis (per 6.1.7a) with fast implementation (CE6-1.7a)

- C3: Adjustment preprocessing of 6.1.6 (CE6-1.6)

- C3a: CE6-1.6a

- C3b: CE6-1.6b

It was commented that CE6-1.7g + CE6-1.4a was not tested in CE.

Ideally, the transform should have the following properties:

1. Sharing of as much as possible building blocks for different transform types and sizes

It was commented the term of “building blocks” need to be clarified.

1. Implementation either as matrix multiply or fast algorithm, independent of specification

A fast algorithm refers to a method that has either benefit for HW or SW implementation. If it is noted that an algorithm has disadvantage for HW or SW implementation, it needs to be described.

It was commented that it should be clarified that whether a fast algorithm is applicable for encoder, decoder or both.

It was commented by the proponent of C2 that, “any fast implementation of DST-4/DCT-4 transforms lead fast implementation of the DCT-2 transform for double size, and any faster algorithm than the current partial butterfly for dct2 leads to faster DST-4/DCT-4 transforms, as they are only the odd basis. Thus, the current proposal aims at being fully compatible with the current dct2 design. Further normative/non-normative improvement of dct2 will improve the DST-4/DCT-4 transforms design.”

* C1: It is claimed to have a fast algorithm, which supports dual implementation, which means it can be implemented as either matrix multiply or fast algorithm, independent of specification. The fast algorithm is not DCT-2 style.
* C2: There is no fast algorithm available yet. However, it is commented by the proponent that maybe fast algorithm for C2 is available and can reduce each operation but need to confirm. The proponent mentioned that evidence will be shown next JVET meeting.
* C3a: This method does not support dual implementation. It is commented that the proposed method can be implemented as filtering operations stage added by matrix multiplication or DCT-2 style fast algorithm.
* C3: Same comments of C3a also applies.

1. Implementation with 16-bit logic (at least for 10-bit video)
   * C1: Support 16-bit logic

* C2: Support 16-bit logic
* C3a: The CE test does not support 16-bit logic, but it is mentioned by the proponent that a modified implementation supports 16-bit logic between two stages (as proposed in JVET-L0682).
* C3b: Same comment of C3a applies.

1. As low complexity as possible.

HW:

* It was questioned whether this non-DCT-2 style fast algorithm benefit for HW, but it does no harm vs matrix multiplication. It was commented that the fast algorithm may be more complex than DCT-2 butterfly. It was commented that the fast algorithm does not benefit for hardware. It was also commented that the fast algorithm may be not easy to implement for HW, however, it has a fall back solution, which is full matrix multiplication.
* C2: Same as matrix multiplication.
* C3a: It was commented by a HW expert that the fast method does not fit their decoder transform HW design because it has different input bit-depth of the normal forward DCT-2, and it does not have a fall back solution (single matrix multiplication). It was mentioned in JCTVC-G132 that forward+inverse DCT-2 has 17-21% more area than inverse DCT-2 only, it is unknown what is the HW cost to implement DST-7/DCT-8.
* C3b: Same comments of C3a apply to C3b.

SW:

* C1: The proposal is for 16-pt and 32-pt transforms used for MTS, but can be extended to 64-pt. Evidence on the benefit has been shown for SW (in terms of run-time). It was commented that HEVC 4x4 DST-7 has a similar fast algorithm implemented in the reference SW.
* C2: No fast algorithm.
* C3a: It was commented that the proposal may not benefit for SW optimization, and it could be even worse than full matrix multiplication, because the forward DCT-2 is used in decoder, which applies multiplications with over 16-bit input due to butterfly first structure of forward DCT-2. It was commented that it is the most important for SIMD optimization to have 16-bit multiplication. It was commented that forward DCT-2 should be avoided at the decoder for SW.
* C3b: Same comments of C3a apply to C3b.

Others:

* C1:
* C2: No fast algorithm
* C3a: It was commented by the proponent that the algorithm still benefit for encoder side. It was also mentioned that there was a JCTVC contribution JCTVC-G132, claiming that matrix multiplication is a useful feature for some scenarios, including DSP, ARM. However, it is questioned by the proponent whether this contribution has valid conclusion.
* C3b: Same comments of C3a apply to C3b.

1. Re-usability of legacy building blocks might be desirable
   * C1: It was commented that existing implementations faster than matrix multiply would not be able to utilize the benefit of this proposal.
   * C2: It was commented that existing implementations faster than matrix multiply would not be able to utilize the benefit of this proposal.
   * C3a: It was commented that existing implementations faster than matrix multiply would not be able to utilize the benefit of this proposal. It was commented by the proponent that the proposed method re-use current DCT-2 with adjustment stages, and different opinions have been expressed by a non-proponent.
   * C3b: Same comment of C3a also applies.
2. Specification as matrix multiply, or cascade of matrix multiplies, or other e.g. butterfly
   * C1: Single matrix multiply
   * C2: Single matrix multiply
   * C3a: Cascade of two matrix multiplies for 16-point and 32-point MTS transforms.
   * C3b: Cascade of two matrix multiplies for 16-point and 32-point MTS transforms.

It was commented that bullet #6 duplicates #7.

1. Extraction of smaller transform sizes from largest size 64 (32 for MTS transforms)

For the following methods, the extraction of smaller transform sizes includes a sub-sampling of the largest transform core coefficients.

* + C1: For applying DCT-2, same as HEVC. For applying other transform types (DST-7, DCT-8), extraction (from a 64x64 matrix) is done according to transform type, where offsets are different for different transform cores, and sign changes are required.
  + C2: For applying DCT-2, same as HEVC. For applying other transform types (DST-4, DCT-4), extraction (from a 64x64 matrix) is done according to transform type, where offsets are different for different transform cores, and sign changes are required.
  + C3a: For applying DCT-2, same as HEVC. For applying other transform cores, no need to extract DST-7, DCT-8, but it is needed to extract DCT-2 and apply transpose, additional adjustment stage is required, but not for extraction.
  + C3b: Same comments of CE3a also applies.

Furthermore, each of the methods should be implementable with 16-bit logic (However, it should be investigated whether this might have impact on low QP cases)

It was requested in CE6 description document that:

* For experiments which have impact on the transform precision, i.e., modifications on shift operations in transform, modifications on bit-depth of intermediate data representation, results using low-QP configurations, i.e., QP 5, 10, 15 and 20 shall be provided as supplemental information.
* C1:
  + For the method proposed in CE6-1.4a: the low QP results will be provided in a late contribution.
* C2:
  + Low QP results not available.
* C3a:
  + For the method proposed in CE6-1.6a: the low QP results will be provided in a late contribution.
* C3b:
  + Low QP results not available.

Analysis of complexity, number of cycles to compute inverse transform, necessary bit depth of implementation stages, etc. should be provided (confirmed by proponents).

Complexity (operation counts):

Primary transform used for MTS0 (e.g., DCT-2, COT):

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Size | Mult | | | Add/Sub | | | Shift | | |
| C1 | C2 | C3 | C1 | C2 | C3 | C1 | C2 | C3 |
| 16-pt | 86 | 86 | 86 | 100 | 100 | 100 | 16 | 16 | 16 |
| 32-pt | 213 | 342 | 342 | 287 | 372 | 372 | 32 | 32 | 32 |
| 64-pt | 833 | 1366 | 1366 | 1069 | 1428 | 1428 | 64 | 64 | 64 |

It was commented by the proponent of C2 that, maybe fast algorithm for C2 is available and can reduce each operation, but it needs to be confirmed. The proponent will show the evidence by next meeting.

Primary transform used for MTS1 (e.g., DST-7/DCT-8, DST-4/DCT-4):

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Size | Mult | | | | Add/Sub | | | | Shift | | | |
| C1 | C2 | C3a | C3b | C1 | C2 | C3a | C3b | C1 | C2 | C3a | C3b |
| 16-pt | 127 | 256 | 182 | 160 | 155 | 240 | 210 | 203 | 16 | 16 | 34 | 34 |
| 32-pt | 620 | 1024 | 534 | 470 | 718 | 992 | 594 | 587 | 32 | 32 | 66 | 66 |

Number of stages to compute inverse transform:

|  |  |  |  |
| --- | --- | --- | --- |
| Size | Mult | | |
| C1 | C2 | C3 |
| 16-pt | 1 | 1 | 2 |
| 32-pt | 1 | 1 | 2 |

Necessary bit depth of implementation stages:

C1:

Internal bit-depth may go up to 18-bit

C2:

Full matrix multiplication

C3:

16-pt DST-7/DCT-8: Internal bit-depth may go up to 19-bit

32-pt DST-7/DCT-8: Internal bit-depth may go up to 20-bit

Between Forward DCT-2 and adjustment: at least 20-bit (current CE code), it is mentioned that there is a modified version which has 16-bit internal bit-depth between the Forward DCT-2 and adjustment, the filter coefficients used for the adjustment stage is up to 128 (which may be regarded as 9-bit coefficient, but the range is within 8-bit).

Output is 16-bit

Memory (for storing primary transform cores based):

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| VTM-2.0.1 | C1 | C2 | C3a | C3b |
| 8.52 KB | 5.12 KB | 5.12 KB | 5.48KB | 5.33 KB |

**Conclusions of BoG:**

It was commented by several non-proponents representing HW companies that none of these three candidates would be a solution that they are confident to provide a complexity reduction compared to matrix multiply. They would encourage further work to find solution that would provide complexity reduction for HW implementations.

Discussion after presentation of BoG report in track A:

- Further study (CE) is necessary.

- The MTS transforms obviously have properties that do not allow as efficient implementation as it is the case in DCT-2. For small block sizes, implementers might even prefer doing a full matrix multiplication rather than a fast algorithm with more complicated data flow and less regularity

- A possible restriction of maximum complexity could probably be achieved by restricting the block size further (as it is currently already restricted to maximum of 32-length transforms). Data for knowing what the disadvantage in compression by imposing further restriction would be shall be collected in the CE, along with experimenting on fast algorithms.

- Lower QP ranges should also be tested to investigate impact of precision.

*CE* related *contributions:*

[JVET-L0060](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4141) CE6-related: Unified matrix for transform [K. Choi, K. P. Choi (Samsung)]

This contribution presents a unified matrix for all kernels of transform. Currently, VTM2.0 uses three types of transform as DCT2, DCT8, and DST7 depending on supported block size. The proposed a matrix in this contribution can provide all three types of transform with all block sizes from 4x4 to 64x64 by using a 64x64 matrix designed with 8-bit representation. Testing results on the proposed method show 0.0%, 0.1%, 0.1% and 0.2% BD rate losses on average for All Intra (AI), Random Access (RA), Low Delayed B (LDB), and Low Delayed P (LDP) configurations, respectively, compared to VTM configure setting, and 0.0%, 0.1%, and 0.0% BD rate losses on average for AI, RA, and LDP respectively, and 0.1% gain for LDB configuration, compared to BMS configure setting.

A method of combining CE6-1.7g and 8-bit transform is proposed, however, the 8-bit transform is different from the one proposed in CE6-1.3. Further study is recommended if the current CE6-1.7g is to be continued.

[JVET-L0304](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4399) CE6-Related: Multiplication Free Transform [M. Salehifar, M. Koo, S. Paluri, J. Lim, S. Kim (LGE)]

This contribution proposes multiplication free transform which consists of only additions (subtraction) and shifts, which could be applied for any transform including MTS candidates. The proposed technique is tested with different maximum number of the allowable terms for the shifts and additions. In particular it is tested with: 1) Allowing 5 terms of shifts, 2) Allowing 4 terms of shifts, and 3) Allowing 3 terms of shifts.

As first test results with allowing maximum 5 terms of shifts compare to VTM anchor, has identical performance.

As second test results with allowing maximum 4 terms of shifts compare to VTM anchor, BD-rate difference of 0.00% (AI), 0.01% (RA), and -0.01% (LDB) is observed.

As third test results with allowing maximum 3 terms of shifts compare to VTM anchor, BD-rate difference of 0.11% (AI), 0.05% (RA), and -0.01% (LDB) is observed.

It was commented that the proposed method may be too dedicated for particular transform type and may not really benefit in case different transform types need to be supported.

[JVET-L0353](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4450) CE6-related: MTS using DST-4 and transposed DCT-2 [Y. Lin, J. Zheng, Q. Yu, N. Zhang (HiSilicon), C. Zhu (UESTC)]

This document presents a low-complexity MTS (multiple transform selection) approach for VVC. It is proposed to use DST-4 and transpose of DCT-2 as transform cores for the MTS, due to benefits of reusing circuit implementation of existing DCT-2 transform, reusing transform coefficients of existing DCT-2 transform and enabling partial butterfly implementation for the proposed transpose of DCT-2. Test results reportedly show coding performance of 0.06%/0.06%/-0.04%/0.03% on average for AI/RA/LDB/LDP configurations compared to BMS-2.0.1 with VTM configuration. Encoding and decoding time slightly decrease due to partial butterfly implementation of the proposed transpose of DCT-2.

It was noted that a forward DCT-2 is needed at the decoder side. The proposed method enables DCT-2 butterfly for one MTS transform type, and it is one stage calculation, for the other transform type, DST-4 is used, which does not have a fast method currently. The performance loss is relatively higher for Class A, average loss is small (below 0.1%). It was mentioned by the proponent that the coding performance of the proposed method is slightly better than CE6-1.7a under CTC. The proposed method looks interesting for complexity reduction of MTS transform types. Further study in CE is recommended.

Recommendations related to non-CE contributions were confirmed in track A.

[JVET-L0688](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4802) BoG report on CE8 & CE15 related contributions [Y.-C. Sun, X. Xu]

Mandates according to the meeting notes:

* To review the contributions from 7.8, 7.15, 7.17, and recommend items to be investigated in the upcoming CE8 and CE15
* To access memory requirements of current-CTU CPR

See the disposition about the documents in sections 7.8, 7.15 and 7.17.

It is reported and confirmed by experts that CPR memory usage with current CTU restriction is calculated as 22.5KB (=3\*(64\*64 +2\*32\*32) \*10)/(1024\*8) ) This needs to be local memory

Others:

It is commented that it is better to have another name for Screen Content (as it also includes gaming and other content that reflects the market). Experts also commented that Screen Content is actually a good name.

Conclusions

The BoG reviewed the all assigned proposals and futher confirmed the calculation of the memory usage of CPR with 1-CTU (current CTU) restriction to be correct.

The BoG recommended:

* to futher study 8 tests in the next CE.
* to update Class F with more representive materials.
* to use CPR with current CTU restriction (CE8.3.1b) as CPR anchor in the next CE
* to use CE palette of CE15.2 as the palette anchor in the next CE pending on further discussion as to which palette design to be used (the joint palette or separated palette).

In the track A discussion, further aspects of CPR are discussed as follows:

- The main concern about CPR is additional local memory

- The compensation itself is integer-precision and simple

- The problem of interfering with loop filter is resolved when restricted to current CPR

From current results, CPR is the best solution in terms of giving benefit for screen content.

There is agreement to have support for screen content in VVC.

Concern is still expressed about the fact that the local memory is too large

Decision: Adopt CPR with restriction to using the current CTU as the reference area under condition

* Specification text was later provided in a revision of L0293 and was reported to have seemed adequate to B. Bross.
* Investigate in CE what the impact would be if the local memory is further reduced (e.g. to a 64x64 area)
* Non CTC condition

New proposals for improving syntax, expressing how to restrict local memory etc. should not be investigated in CE, be handled as non-CE at next meeting.

Proposals which use CPR beyond the current CTU shall not increase the local memory footprint. [Ed. Check with Jens and Jill on that. It seems like the sort of statement we would not ordinarily make.]

Further discussed 11 Oct (chaired by J. Boyce). Updated contribution with specification text has been provided. Waiting on feedback by B. Bross.

[JVET-L0691](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4805) BoG report on CE4 related contributions [H. Yang]

Reviewed 1500- Monday (GJS)

Three sessions were held, 1600 ~ 2100 on Oct. 5, 0900 ~ 1400 on Oct. 6, and 1400 ~ 2400 on Oct. 7, for discussing 65 technical contributions in six categories,

* Affine motion compensation (17)
  + Line buffer reduction & CPMV unification
  + Harmonization with other tools, e.g., AMVR, MMVD, merge offset
  + Miscellaneous
* Merge mode enhancement (29)
  + ATMVP modifications
  + HMVP modifications
  + Miscellaneous
* Motion vector coding (5)
* Weighted prediction (3)
* Local illumination compensation (3)
* Memory bandwidth reduction (8)

Recommended adoptions to VTM

* Normative changes
  + Unification of affine CPMV, choose L0047 method 1 or L0047 method 2 (the same as L0373)
    - Method 1 control point MVs are stored and used only for model inheritance, other places (ATMVP storage, deblocking, motion comp, spatial neighbours for merge list, AMVP list derivation) use subblock MVs calculated from the control point MVs. This method has some extra memory (~768 bytes for hardware implementations) and a small benefit (0.05% average). It was commented that a new contribution L0666 reported that the peak loss for method 2 for some non-CTC affine-friendly sequences was substantially bigger. Method 2 is reportedly always (a little) worse in coding efficiency. Another late contribution reports a way to reduce the extra memory. If the subblock size is made bigger, method 2 would have some inconsistency in the motion vector field relative to the model. Decision (design cleanup): Adopt method 1 as the more consistent and “clean” design (roughly neutral on coding efficiency 0.01%). Further study of other schemes is anticipated.
    - Method 2 uses CPMVs to calculate sub-block MVs for non-corner subblocks within the CU, and some corner subblocks have MVs overwritten by CPMVs. The set of the resulting subblock MVs are used for all operations.
  + ATMVP modification: use fixed subblock size 8x8 for ATMVP (L0198, L0468, L0104, possibly some others). Currently we’re adaptively using 4x4 or 8x8 subblock size, but this has no benefit. Decision: Agreed (approx. no coding efficiency impact).
  + ATMVP modification: restrict ATMVP mode to CUs of which both the width and height are larger than or equal to 8 (L0055), note that this is already a part of 4.2.8 which had been adopted. Decision: Agreed (approx. no coding efficiency impact).
  + ATMVP modification: check the first spatial neighbouring motion vector and use this as the reference motion vector for the collocated position for motion vector derivation (L0198). Decision (complexity reduction): Agreed (approx. no coding efficiency impact).
  + Reset the FIFO table in each CTU row for HMVP (L0106, L0158 method 1). Decision (complexity reduction): Agreed (approx. no coding efficiency impact).
  + Merge index coding: use one context for the first bin of the full-block merge index and bypass coding of other bins (L0194). After discussion, it was noted that this had not been tested for the subblock merge list and we don’t want different syntax for the two cases. Further study in a CE was planned to test doing the same thing for the subblock merge list. Decision (complexity reduction): Agreed (for the full-block merge index only at this time, approximately no coding efficiency impact).
  + Generalized bi-prediction (L0646). About 0.66% gain on RA, about 6% increase in encoding runtime. There was discussion of the alternative of using weighted prediction with multiple weights per picture. Weighted prediction would probably work better than this for fade-in, fade-out, and cross-fades (e.g., since it doesn’t need block-level weight selection and since it can extrapolate as well as interpolate), so this proposed method is not a complete replacement for weighted prediction. It was commented that there had been previous contributions describing a benefit for using weighted prediction with multiple weights, and there is some support in the JM for this sort of usage, but not in the HM. AVC had an extra, implicit mode of weighted prediction that was not adopted into HEVC, but it used POC weighting rather than signalling to establish the weights. A proponent noted that the syntax of weighted prediction does not have a shortcut for biprediction with two weights that add up to 1, so the proposed signalling of what is proposed as “generalized biprediction” for VVC would be more efficient when that constraint is intended to apply (e.g., the equivalent of selecting among 5 pairs of weights that add up to 1 would require selection among many more possibilities). Decision (coding efficiency): Adopt L0646 (0.66% coding efficiency; weighted prediction should also be put in the draft, but this and weighted prediction would be mutually exclusive at the picture level, when used with OBMC the weights of the neigbours would apply for the neighbour predictors, which is how the BMS software already does it, no consideration in deblocking filter). Further study of alternative approaches is expected and encouraged.
  + Prohibit 4x4 bi-prediction for inter CU (L0104). Decision (complexity reduction): Agreed (negligible effect on coding efficiency). Further study is planned for other related aspects.
* Bugfix of VTM software
  + Align the software with the draft text regarding ATMVP motion vector clipping (L0257). Decision (change software to match text): Agreed.
  + Rounding motion vectors toward zero rather than toward minus infinity for AMVR (L0377). Decision (change software to match text): Agreed.
* Encoder optimization
  + Encoder optimization for affine motion estimation (L0260). Decision (software): Adopt (0.3% coding gain, 3% encoding time increase).

Further CE4 tests were recommended based on the following contributions

* Affine motion compensation: L0046, L0281, L0273, L0330, L0259, L0332, L0305, L0320, L0389, L0193, L0522
* Merge mode enhancement: L0092, L0105, L0119, L0302, L0309, L0401, L0091, L0144, L0171, L0207, L0214, L0216, L0319, L0470
* Motion vector coding: L0300, L0301, L0355, L0408
* Local illumination compensation: L0120
* Memory bandwidth reduction: L0122, L0396

Open issues identified by BoG were discussed Tuesday 1100 (GJS)

* Requested review in track
  + L0093 align VTM with draft text regarding the pruning of regular merge list (the same as L0282). The draft text does not do full pruning for the spatial and TMVP candidates in the merge list. The software does full pruning. It was reported that there is no loss for not doing full pruning. Decision (bug fix): Align software with text.
  + Whether various LIC (local illumination compensation) techniques can be further studied in CE. LIC schemes can provide about 0.7% coding gain. These schemes have a pipeline dependency problem. Some other techniques do too (e.g., diffusion filter, combined intra-inter coding, Hadamard filter, and bilateral filter). It was commented that we need to control the number of tools of this sort that we would use together, and perhaps make them mutually exclusive. There are some common elements between LIC and CCLM. It was suggested to group together such proposed tools that operate in the post-reconstruction stage of the processing pipeline and to test ways to use these without cascading. CE study was planned.
  + L0265 to set the chroma subblock size to 4x4 instead of 2x2 for affine motion compensation by averaging the MVs of the 4x4 luma subblocks. It was commented that SIMD implementation is feasible for 4x4 but not 2x2. This has a negligible coding efficiency effect. It was noted that we also have 4x4 ordinary CUs, so this doesn’t entirely solve the 2x2 problem, but would leave that as the only case where this occurs. This would apply to both uni an bi-prediction. Decision (complexity reduction): Adopt.
  + L0317 sub-block MV clipping in affine prediction. This proposes that the maximum MV difference within an 8x8 area is constrained to +/−1 full-pel difference. This reportedly has a negligible loss (~0.02%). This would apply to both uni- and bi-prediction. There is also another proposal L0396 and also a third proposal L0122 and a fourth proposal to restrict the minimum subblock size to 8x4/4x8 for biprediction. The proponent of L0317 said the L0396 proposal has higher memory bandwidth and higher coding loss (although the loss is very small in both cases). Details of the comparisons and calculations used at the subblock level in L0317 and versus the block level for L0396 were discussed. It was planned to further study these techniques and test them in a CE, since multiple approaches could solve the problem.
  + L0168 on 16-bit motion vector constraint. MVs currently require 18 bits (due to having 1/16th pel precision). This proposes several ways to reduce the storage (for temporal MV storage or the local line buffer or both). One of these is to not store that full range, but rather clip the stored MVs to a 16 bit range. Another approach has an adaptive precision, and a third approach removes the two LSBs of fractional precision. For very large picture sizes (e.g., for 360° video) this would not allow the whole reference picture to be addressed. This was suggested to be unnecessary for action at this stage of the work, so this was deferred for further study at a later time.
* L0048, L0390, L0425, L0187
  + L0048 had two proposed elements, part of it was the same as L0046. These will be tested in a CE.
  + A new document L0694 was submitted that was related to L0048, testing in combination with other actions taken at the meeting.
  + L0425 was agreed to be studied in a CE since there are competing proposals
  + L0390 had two schemes in it – the simplification aspect was agreed to be studied in a CE
  + L0187 was missing some test results but was preliminarily showing some coding gain. Further study in a CE was planned.
* Contribution not reviewed in BoG.
* L0201 on weighted prediction – see notes for that topic.

[JVET-L0692](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4806) BoG report on CABAC [F. Bossen]

The BoG on CABAC met on Sunday Oct 7, 2018 between 4:30pm and 6pm.

The topic of discussion was defined as follows in the JVET-L meeting notes:

*Considering the fact that the total memory even in worst case is less than one line buffer of a video, memory is asserted to be not a critical issue here.*

*Throughput (pipelining, number of cycles) could be a more critical issue. The probability estimate is probably OK, but potentially multiple context models, and customized window could cause problems. More analysis on this is needed. BoG (F. Bossen, M. Zhou) to look into this.*

Suggestions from the BoG include:

* Further study the issue of CABAC complexity until the 13th JVET meeting
* For HW, do in-depth analysis on paper (two companies volunteered)
* For SW, set up a test framework that can be used to measure throughput (two companies volunteered)

Subrange computation (from CE5.2/5.3)

AVC/HEVC: lookup table 64x4x8 bit

Options:

1. [Add/xor] + table lookup 32x8x8 bit (or other)
2. [Add/xor] + multiplier 5x4 (and upwards)
3. [Add/xor] + table lookup (32x7 or 16x7 bit) + multiplier (7x4)
4. [Add/xor] + lzcnt + multiplier 5x5 (and upwards)
5. [Add/xor] + lzcnt + lookup 8x8x8 bit

All solutions can be implemented using lookup table, except CE5.2.4 (also needs lzcnt).

Each solution may require a specific implementation when using a multiplier (except CE5.2.3 for which multiplication-based implementation may not be possible)

Probability estimation (from CE5.1)

AVC/HEVC: lookup table 64x2x7 bits

Options:

1. Add + fixed shift (x2)
2. Add + fixed shift (x2) + counter
3. Add + variable shift (x1)
4. Add + variable shift (x2)
5. Table lookup (32x8 bits) + fixed shift + add (x2)
6. Table lookup (32x8 bits) + variable shift + add (x1)
7. Table lookup (32x8 bits) + variable shift + add (x2)

Note: for case with table lookup, table encodes a piece-wise linear function.

How to determine throughput?

HW

Some analysis in JVET-L0094 (TSMC 12nm)

All CE5.2 experiments (range computation) were synthesized.

Multiplication requires smaller area, but LUT has shorter critical path.

Note: it was mentioned that critical path contains initial xor operation.

No results for HEVC (but could be provided).

Since most (or all) CE5.2 and CE5.3 proposals can be implemented using a lookup table, all proposals seem adequate for HW implementation.

Is it realistic to do synthesis exercise for entire engine? Probably not.

Should do paper analysis by next meeting to determine throughput estimate. Volunteers: HHI, Qualcomm

SW

More realistic (than for HW) to implement a fast version of entire engine.

Suggestion:

Measure run time in a test framework using artificial bit streams. May encode/decode either using single context, or using multiple contexts.

Looking at decoder should be sufficient, as there are fewer feedback loops in encoder.

Open question: how to cross-check optimized implementations?

Volunteers: Sharp, HHI

Conclusion:

* More study on complexity impact needed before making a decision on the CE5 contributions
* Continue CE on investigating the effect of training customized window sizes together with initialization; to be investigated for cases of multiple and single probability models (and multiple probability models without customized windows)

[JVET-L0693](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4807) BoG report on CE9 related contributions [X. Xiu]

Reviewed 1415-1500 Monday (GJS)

The BoG on CE9-related: decoder-side motion vector derivation met on October 7, 2018 from 6:00PM to 8:00PM in room 1006. It reviewed input CE9-related contributions on decoder-side motion vector derivation.

Notes from the BoG report are integrated with the relevant contributions in this report.

[JVET-L0704](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4822) BoG report on Neural Networks for Video Coding [S. Liu, Y. Li]

The BoG on Neural Networks for Video Coding met on 11 October 2018. The BoG discussed several subjects including: training data set and process, software sharing and simulation, neural network structure and complexity analysis, reporting and comparison procedure, etc. The BoG recommended:

* To use Div2K as the base training set for all proposals; [Add link.]
* To establish a software branch for neural network coding tools (proposals);
* A template to report neural network structure and complexity;
* To consult with hardware experts about practical complexity criteria;
* To continue discussing related issues in an ad-hoc group.

The BoG outcome was reviewed Fri 12 Oct 0930 (GJS).

It was noted that the Div2K contains only still images (and only 800 of them). Its use was only encouraged in order to ease comparisons if applicable. Contributors may use other data for training, but need to describe what they did.

No particular training platform was selected, but the method should be described, and the amount of time spent on the training should be described.

Among the proposed technologies at this meeting, the training was always something that had been done offline, not as part of the sequence coding/decoding process.

It was clarified that the study is encouraged to include not only proposed normative elements that would affect the decoding process, but also other aspects – e.g., encoder-only processing (for mode decisions, partitioning, etc.) and pre-/post-processing.

There had been some discussion of potential cross-checking of the training. This might involve source code exchange, using a common training platform, and using common initialization.

It was commented that it does make some difference whether the test set is used in the training process. However, strictly controlling for this does not seem necessary at this stage of the investigation.

It was noted that, in some cases, specific QP values were used in the training.

It is unknown whether this study will really affect the development of this standard. It was acknowledged that there are substantial complexity issues involved in some of these proposals.

Several proponents were willing to share their software. It was noted that forking the VTM software is not difficult. Restriction of access to members is also not difficult if desired. It was noted that uploading and updating excessively large files needs to be avoided.

Some complexity analysis had been done in the BoG; further work on this was encouraged.

For reporting of runtimes, it needs to be clear whether that is GPU or CPU, and CPU runtimes were desired to be provided if applicable.

A template had been developed and was attached to the BoG report for use in reporting of results and analysis. Its use in further experiments was encouraged.

## List of actions taken affecting Draft 2 of VVC, VTM 2, BTM and 360Lib

The following is a summary, in the form of a brief list, of the actions taken at the meeting that affect the text of the VVC draft text, VTM or 360Lib description. Both technical and editorial issues are included. This list is provided only as a summary – details of specific actions are noted elsewhere in this report and the list provided here may not be complete and correct. The listing of a document number only indicates that the document is related, not that it was adopted in whole or in part.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Category** | **Sub-Category** | **Rationale** | **Modification** | **AI BD-R Y** | **RA BD-R Y** | **Doc.** | **Text** | **Notes** |
| **Inloop Filter** |  |  |  |  |  |  |  |  |
| Inloop Filter | ALF | complexity reduction | 10 b coeffs (instead of 11) | 0.0% | 0.0% | JVET-L0082 | In JVET-L0082 OK | Decision (complexity reduction): Adopted |
| Inloop Filter | ALF | complexity reduction | Subsampling of classifiers | 0.0% | 0.0% | JVET-L0147 | In JVET-L0147 OK | Decision (complexity reduction): Adopt 2.6.2 |
| Inloop Filter | ALF | complexity reduction | Reduction of bits for ALF coefficient fractional part | 0.1% | 0.1% | JVET-L0083 | In JVET-L0083 OK | Decision: Adopt (text is in the contribution). |
| Inloop Filter | ALF | complexity reduction | Disabling 5x5 ALF for luma component | 0.0% | 0.0% | JVET-L0664 |  | Decision: Remove the alf\_luma\_type\_flag and the conditioning on it that results in signalling of 5x5 as a special case for luma. |
| Inloop Filter | SAO | editoral | Add SAO text from HEVC |  |  |  | HEVC | Decision: Add SAO as found in HEVC to the draft standard |
| Inloop Filter | DF | coding efficiency | Luma Adaptive Deblocking Filter QP Offset | 0.0% | 0.0% | JVET-L0414 | In JVET-L0414 OK | Decision: Adopt JVET-L0414. Other from the proposal, which makes the QP offset dependent on transfer function, the values shall be signaled in the SPS. Default is not applying (enabling\_flag=0). If the flag is 1, another syntax element follow indicating the number of intervals (2bits for 2,3,4,5), and then the luma threshold values and QPoffsets between the intervals. |
| Inloop Filter | DF | bug fix | tC table fix | 0.0% | 0.0% | JVET-L0410 | straightforward | Decision: Adopt JVET-L0410, updated tC table into VVC text & VTM |
| Inloop Filter | DF | editorial | Add text from HEVC replacing prediction block with CU subblock |  |  |  | HEVC | The text provided by B. Bross was reviewed by the BoG on Oct 11, 2018 (9:30 am). The BoG recommended to use this text in the current version of the VVC deblocking. K. Andersson volunteered to provide a software implementation to match the text. A.M Kotra volunteered to cross-check. Decision: The recommendation of the BoG was agreed in JVET. For CE work on any other subblock-base modes (planar MV mode and others if any), the same scheme should apply (at least as an anchor). |
| **Intra** |  |  |  |  |  |  |  |  |
| Intra | Angular | complexity reduction | Unification of angular intra prediction for square and non-square blocks | -0.1% | 0.0% | JVET-L0279 | In JVET-L0279 OK | Decision: Adopt JVET-L0279 |
| Intra | Angular | coding efficiency | Multi-reference line intra prediction | -0.4% | -0.2% | JVET-L0283 | In JVET-L0283 OK | Decision: Adopt JVET-L0283 version 1.1.4 (with line restriction from CTU above). |
| Intra | Angular | coding efficiency | Intra DCTIF / Gaussian interpolation filter | -0.5% | -0.2% | JVET-L0628 | In JVET-L0628 OK | Adopt JVET-L0628 3.1.4.2 (as this filter is used somewhere else in the design) |
| Intra | CCLM | complexity reduction | CCLM Replace the LMS algorithm by a straight-line equation | 0.1% | 0.1% | JVET-L0191 | In JVET-L0191 OK | Decision: Adopt JVET-L0191 conditional on providing acceptable specification text. |
| Intra | CCLM | complexity reduction | CCLM line buffer restriction at top CTU boundary (1 line) | 0.0% | 0.0% | JVET-L0136 | In JVET-L0136 OK | Decision: Adopt JVET-L0136 conditional on providing acceptable specification text. |
| Intra | CCLM | coding efficiency (chroma) | CCLM MDLM | 0.0% | 0.0% | JVET-L0338 JVET-L0340 | In JVET-L0340 OK | Decision: Adopt JVET-L0338 method 5.4.2/JVET-L0340 method 5.6.1 |
| Intra | Mode Coding | coding efficiency | Chroma DM modification | -0.1% | 0.0% | JVET-L0053 JVET-L0272 | JVET-L0272\_r1.docx | Decision: Adopt JVET-L0053 first aspect / JVET-L0272. Proponents shall check if their text is identical and if not, unify them. |
| Intra | Mode Coding | coding efficiency | Extended MPM list (CE3 6.2.1) | -0.3% | -0.1% | JVET-L0165 | In JVET-L0165 OK | Decision: Adopt JVET-L0165. Text was reviewed in BoG. It is however pointed out that there is an inconsistency in the specification of coding the remaining modes. The software codes them as truncated binary, whereas the text specifies fixed length coding (as was used with 3 MPM before). To be confirmed by text editors that the specification is corrected. |
| Intra | PCM | functionality | PCM mode with dual tree partition | 0.0% | 0.0% | JVET-L0209 | In JVET-L0209 OK | Decision: Adopt. |
| Intra | CPR | coding efficiency | Current picture referencing with current CTU restriction (CE8 8.3.1b) | -0.2% | -0.1% | JVET-L0293 | In JVET-L0293 OK | Decision: Adopt CPR with restriction to using current CTU as reference area under condition - Investigate in CE what the impact would be if the local memory is further reduced (e.g. to a 64x64 area)  - Non CTC condition |
| **Trafo** |  |  |  |  |  |  |  |  |
| Trafo |  | complexity reduction | 8-bit transform matrix (CE6 6.1.3) | 0.0% | 0.0% | JVET-L0285 | In JVET-L0285 OK | Decision: Adopt JVET-L0285 (8-bit transform matrices |
| Trafo |  | bug fix | Unifying signalling for inter/intra (CE6 6.1.7b) | 0.0% | 0.0% | JVET-L0118 | In JVET-L0118 OK | Decision (BF): Adopt JVET-L0118 |
| Trafo |  | complexity reduction | Remove dependency on number non-zero coeff. for MTS | 0.0% | 0.0% | JVET-0059 | In JVET-L0059 OK | Decision: Adopt JVET-L0059. |
| **Quantization** |  |  |  |  |  |  |  |  |
| Quantization |  | functionality | Quantization parameter signalling | 0.0% | 0.0% | JVET-L0362 | In JVET-L0362 OK | Decision: Adopt method 1 (depth is QT depth + BT depth) |
| Quantization |  | functionality | Delta QP and Chroma QP Offset for Separate Tree | 0.0% | 0.0% | JVET-L0428 | In JVET-L0428 OK | Decision: Adopt first aspect (use centered position to fetch collocated luma QP). |
| Quantization |  | bug fix | Fix of Initial QP Signalling | 0.0% | 0.0% | JVET-L0553 | In JVET-L0553 OK | Decision (bug fix): Adopt second fix to semantics of init\_qp\_minus26 where +25 is changed to +37 |
| **CABAC** |  |  |  |  |  |  |  |  |
| CABAC | Coeff coding | complexity reduction | Reduction of number of context-coded bins (CE7 7.1.3b) | -0.2% | -0.1% | JVET-L0274 | In JVET-L0274 OK | Decision: Adopt JVET-L0274, version 7.1.3b. |
| CABAC | Ctx modelling | coding efficiency | Context modeling of CU split modes | -0.1% | -0.1% | JVET-L0361 | In JVET-L0361 OK | Decision: Adopt JVET-L0361 (version with 22 context models) |
| CABAC | Ctx modelling | bug fix | Corrected initial context states for ALF | 0.0% | 0.0% | JVET-L0392 | will change after reinit anyways | Decision (minor BF): Adopted. |
| CABAC | Ctx modelling | complexity reduction | 1 ctx for 1st bin of the full-block merge index and bypass coding for other |  | 0.0% | JVET-L0194 | straightforward | Decision (complexity reduction): Agreed (for the full-block merge index only at this time, approximately no coding efficiency impact). |
| **Inter** |  |  |  |  |  |  |  |  |
| Inter | AFFINE | complexity reduction | Combination of affine mode clean up and line buffer reduction |  | 0.0% | JVET-L0694 | JVET-L0694\_WD-v2.docx | Decision (harmonization of interaction between adoptions): Adopt. |
| Inter | AFFINE | complexity reduction | Line buffer reduction for affine inherited candidates, location 1 (CE4 4.1.11.a) |  | 0.1% | JVET-L0045 | JVET-L0694\_WD-v2.docx | Decision (complexity reduction): Adopt 4.1.11.a (pending consideration of non-CE contributions) |
| Inter | AFFINE | complexity reduction | Unification of affine CPMV |  | 0.0% | JVET-L0047 | In JVET-L0047 OK | Decision (design cleanup): Adopt method 1 as the more consistent and “clean” design (roughly neutral on coding efficiency 0.01%). Further study of other schemes is anticipated. |
| Inter | AFFINE | coding efficiency | Affine merge candidate list (CE4 4.2.6.d + modification in cross-check) |  | -0.7% | JVET-L0366 JVET-L0142 JVET-L0632 | JVET-L0694\_WD-v2.docx | Adopt the variation of 4.2.6.d as modified in L0632 |
| Inter | AFFINE | complexity reduction | Simplification of affine AMVP candidate list construction (CE4 4.1.6.a ) |  | 0.0% | JVET-L0271 | JVET-L0694\_WD-v2.docx |  |
| Inter | AFFINE | coding efficiency | Moving ATMVP into the affine merge list (CE4 4.2.8) |  | -0.8% | JVET-L0369 | JVET-L0694\_WD-v2.docx | Decision: Adopt 4.2.8 moving ATMVP into the affine merge list (assuming ATMVP operates on a subblock basis |
| Inter | AFFINE | complexity reduction | chroma subblock size to 4x4 instead of 2x2 for affine motion compensatio |  | 0.0% | JVET-L0265 | JVET-L0265-WD.docx | Decision (complexity reduction): Adopt. |
| Inter | MERGE | coding efficiency | Pairwise average merging candidates (CE 4.4.12.a) |  | -0.4% | JVET-L0090 |  | Decision: 4.4.12.a (0.38% in RA), merge list size 6 |
| Inter | MERGE | coding efficiency | Merge with MVD (MMVD) aka UMVE (CE4 4.5.4.b) |  | -1.3% | JVET-L0054 | In JVET-L0054 OK | Decision: Adopt UMVE variant b (1.29% in RA); this needs a better name – e.g., merge with MVD (MMVD) |
| Inter | MERGE | coding efficiency | Triangular partitions (CE10 10.3.1.b with bug fix) |  | -0.6% | JVET-L0124 JVET-L0208 | In JVET-L0124 v5 OK | Decision (coding efficiency): Adopt (0.57% in RA, 1.23% in LB), with the L0208 bug fix, flag after combined intra/inter. |
| Inter | MERGE | coding efficiency | Combined merge / intra (CE10 10.1.1.c with restriction) |  | -0.5% | JVET-L0100 | JVET-K1001-v7\_plus\_CE10\_1\_1\_c.docx | Decision (coding gain): Adopt CE10.1.1.c (described in JVET-L0100) combined intra/inter with restriction to w×h >= 64 luma samples (0.5% in RA). |
| Inter | MERGE | complexity reduction | fixed subblock size 8x8 for ATMVP |  | 0.0% | JVET-L0198 JVET-L0468 JVET-L0104 …? | In JVET-L0198 OK | Decision: Agreed (approx. no coding efficiency impact). |
| Inter | MERGE | complexity reduction | restrict ATMVP to CUs w>= 8 && h>=8 |  | 0.0% | JVET-L0055 | In JVET-L0055 OK | Decision: Agreed (approx. no coding efficiency impact). note that this is already a part of 4.2.8 which had been adopted. |
| Inter | MERGE | complexity reduction | first spatial neighbouring MV for collocated position |  | 0.0% | JVET-L0198 |  | Decision (complexity reduction): Agreed (approx. no coding efficiency impact). |
| Inter | MERGE+ AMVP | coding efficiency | History-based MVP |  | -0.6% | JVET-L0266 | JVET-L0266\_spec\_d2.docx | Decision: Adopt history method with merge list size 6, history applied also to AMVP (0.58% gain in RA, |
| Inter | MERGE+ AMVP | complexity reduction | Reset the FIFO table in each CTU row for HMVP |  | 0.0% | JVET-L0106 JVET-L0158 | JVET-L0158-r1.docx | Decision (complexity reduction): Agreed (approx. no coding efficiency impact). |
| Inter | MERGE+ AMVP | coding efficiency | Generalized Bi-prediction |  | -0.7% | JVET-L0646 | JVET-L0646\_DraftText\_r2.1.docx OK | Decision (coding efficiency): Adopt L0646 (0.66% coding efficiency; weighted prediction should also be put in the draft, but this and weighted prediction would be mutually exclusive at the picture level, when used with OBMC the weights of the neigbours would apply for the neighbour predictors, which is how the BMS software already does it, no consideration in deblocking filter). |
| Inter | MERGE+ AMVP | complexity reduction | Prohibit 4x4 bi-prediction for inter CU |  | 0.0% | JVET-L0104 | In JVET-L0104 OK | Decision (complexity reduction): Agreed (negligible effect on coding efficiency). |
| Inter | AMVP | complexity reduction | Simplification on AMVP candidate list construction (CE4 4.1.6a) |  | 0.0% | JVET-L0271 | In JVET-L0271 OK | Decision: Adopt 4.1.6a (text in L0271 to be checked) |
| Inter | BIO MC | coding efficiency | Bi-directional optical flow (BIO) |  | -1.3% | JVET-L0256 | JVET-L0256-BIO\_Text OK | Decision: Adopt |
| **Partitioning** |  |  |  |  |  |  |  |  |
| Partitioning |  | bug fix | Fix relation between QT/BT/TT syntax elements |  | 0.0% | JVET-L0217 | In JVET-L0217 OK | Decision (ed./text improvement): Adopt JVET-L0217 (as per v4) |
| Partitioning |  | functionality | QT/BT/TT syntax overiding in slice/tile group header |  | 0.0% | JVET-L0678 | In JVET-L0678 OK | Decision: Adopt JVET-L0678 |
| Partitioning |  | complexity reduction | Constraint for binary and ternary partitions (CE1 2.1.2) |  | 0.2% | JVET-L0081 | In JVET-L0081 OK | Decision: Adopt JVET-L0081 Test 2.1.2 |
| **HLS** |  |  |  |  |  |  |  |  |
| HLS |  | functionality | Picture order count for VVC |  |  | JVET-L0249 | In JVET-L0249 | Decision: Agreed except as noted below regarding L0449. |
| HLS |  | functionality | Picture Order Count Signalling for VVC |  |  | JVET-L0449 | In JVET-L0449 | Decision: Adopted. The MSBs will still reset to zero at an IRAP and there will be no relation between POCs of different CVSs. (Currently the text does not have a non-IDR IRAP.) However, the software will need changes for this. For now, we can just have the encoder use 0 for the IDRs, but we need to put support for this into the software eventually. The contributor volunteered to work on that. |
| HLS |  | functionality | TemporalId restrictions |  |  | JVET-L0248 | In JVET-L0248 | Decision: Point 2 is agreed, if applicable (i.e., if we have PPSs). Regarding point 3, it is agreed to prohibit referencing any picture in a higher temporal sublayer. |
| HLS |  | functionality | Spec text for the agreed starting point on slicing and tiling |  |  | JVET-L0686 | In JVET-L0686 | Decision: Adopted (as modified). |
| HLS |  | functionality | Proposed starting point for interoperability point syntax |  |  | JVET-L0696 | In JVET-L0696 | The proposed scheme does not consider extensibility, which ultimately needs to be considered. Decision: Adopt. Regarding the question of whether we have a PPS or picture header or both. Decision: Use a PPS for now. The picture header topic as a substitute or additional header is for further study. Whether to have some picture header is primarily a coding efficiency issue. Decision: Regarding including some provision for future extensions in the syntax (e.g., multi-layer extension), it was agreed that may do so in cases where this has a very minor impact on the current design. |
| **Software** |  |  |  |  |  |  |  |  |
| Trafo |  |  | Transform Skip Condition on Transform Block size |  |  | JVET-L0111 |  | Decision (BF/SW): Adopt JVET-L0111 |
| Inter |  |  | Align the software with the draft text regarding ATMVP motion vector clipping |  |  | JVET-L0257 |  | Decision (change software to match text): Agreed |
| Inter |  |  | Rounding motion vectors toward zero rather than toward minus infinity for AMVR |  |  | JVET-L0377 |  | Decision (change software to match text): Agreed |
| Inter |  |  | Encoder optimization for affine motion estimation |  | -0.3% | JVET-L0260 |  | Decision (software): Adopt (0.3% coding gain, 3% encoding time increase). |
| Inter |  |  | align VTM with draft text regarding the pruning of regular merge list |  |  | JVET-L0093 JVET-L0282 |  | Decision (bug fix): Align software with text. |
| CTC |  |  | Class F test sequences |  |  |  |  | Decision (CTC): Make Class F mandatory (but not included in the average). |
| Quantization |  | bug fix | Corrected operation of ALF encoding with perceptually optimized QP adaptation |  |  | JVET-L0181 |  | Decision (SW): adopt. |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |
|  |  |  |  | -1.5% | -7.4% |  |  |  |

### Encoder only or CTC/software changes

JVET-L0XXX: …

As a general rule, sophisticated speedups such as dedicated SIMD optimization need final approval, to be made at the discretion of software coordinators

### Syntax/semantics/decoding process changes VTM/WD

JVET-L0XXX: …

### BMS

All modifications from VTM

JVET-L0XXX: …

### Changes in 360Lib

JVET-L0XXX: …

This does not have normative status – to be used as reference in CE13 as a best-known solution that would not affect the decoding loop.

# Project planning

## Core experiment planning (update)

To clarify about continuation of investigation in CE from track A:

* If something was in a CE before, and it says “further study”, that should be read as “further study in same CE”
* If something was in a CE related category, the meeting notes should explicitly say that CE study is planned.

The following CEs were initially planned (Wed 18th 1630) It was emphasized that this was an initial list, and it was still to be decided after a presentation of an initial CE description if the respective CE will be finally established:

1. Partitioning (J. Ma (primary), M. W. Park, [Thu: Add per document])
2. In-loop filters (L. Zhang, K. Andersson, [Thu: added Y. Tung])
3. Intra prediction and mode coding (G. Auwera, J. Heo)
4. Inter prediction and MV coding (H. Yang, S. Liu)
5. Arithmetic coding engine (T. Nguyen, A. Said)
6. Transforms and transform signalling (A. Said, X. Zhao)
7. Quantization and coefficient coding (M. Coban, H. Schwarz)
8. Current picture referencing (X. Xu, K. Müller)
9. Decoder side MV derivation (S. Esenlik, Y.W. Chen)
10. Combined and multi-hypothesis prediction (C.W. Hsu, M. Winken)
11. Composite reference pictures (X. Zheng)

CE draft developers shall present initial versions of CE proposals Thu. afternoon, containing

* list of sub-experiments, origin of the technology to be investigated (e.g., CfP response document number), expected results, method of investigation
* Participating parties and cross-checkers
* Expected interdependency with other CEs

Interested parties were asked to get in contact with CE draft developers as listed above.

Initial descriptions of CEs 1 and 2 were orally reviewed Thursday 19 April 1600–1630.

For CE1: transform coefficient coding should be used from test (or with minor alignments when necessary by the partitioning); estimated number of configurations that will be tested to be reported on Friday. JVET-J1021

For CE2: It was noted that deblocking in the BMS is already parallelizable. It was suggested to include HDR test sequences in deblocking tests.

Regarding the general rule applying to CE plans established at this meeting, it was confirmed on Friday 20 April (1200, GJS and JRO) that each CE is planned based on technology provided in responses to the CfP, there may be subtests within each CE that are based on other contributions (or hypothetical combinations, etc.), provided there is agreement to include such testing.

It was discussed on 1230 Friday 20 whether the adaptive-resolution CNN technology should be in the intra prediction CE. This seemed to be different from mere intra prediction, as the resolution reduction is also applied to the residual in that scheme. It seemed too late in the meeting to try to define another CE. It was commented that the proposed technology is certainly interesting and should be studied in the AHG 9.

It was furthermore agreed in the Friday plenary that each CE (except the one formed by merging two prior CEs) should have a maximum of 3 coordinators. The role of CE coordinators was again clarified. It is not necessary that each sub-CE has its own coordinator(s). People involved in sub-CEs should communicate with each other about how to compare with each other and agree on a compiled version of their part before sending it to the overall CE coordinator.

## Drafting of specification text, encoder algorithm descriptions, and software

The following agreement has been established: the editorial team has the discretion to not integrate recorded adoptions for which the available text is grossly inadequate (and cannot be fixed with a reasonable degree of effort), if such a situation hypothetically arises. In such an event, the text would record the intent expressed by the committee without including a full integration of the available inadequate text.

## Plans for improved efficiency and contribution consideration

The group considered it important to have the full design of proposals documented to enable proper study.

Adoptions need to be based on properly drafted working draft text (on normative elements) and HM encoder algorithm descriptions – relative to the existing drafts. Proposal contributions should also provide a software implementation (or at least such software should be made available for study and testing by other participants at the meeting, and software must be made available to cross-checkers in EEs).

Suggestions for future meetings included the following generally-supported principles:

* No review of normative contributions without draft specification text
* VTM algorithm description text is strongly encouraged for non-normative contributions
* Early upload deadline to enable substantial study prior to the meeting
* Using a clock timer to ensure efficient proposal presentations (5 min) and discussions

The document upload deadline for the next meeting was planned to be Wednesday 2 January 2019 (a little later than usual due to the proximity of the New Year holiday).

As general guidance, it was suggested to avoid usage of company names in document titles, software modules etc., and not to describe a technology by using a company name.

## General issues for experiments

This section was reviewed in the opening plenary on Wednesday 3 October and on Friday 12 October.

Group coordinated experiments have been planned as follows:

* “Core experiments” (CEs) are the coordinated experiments on coding tools which are deemed to be interesting but require more investigation and could potentially become part of the draft standard by the next meeting.
* A CE is a test of a specific fully described technology in a specific agreed way. It is not a forum for thinking of new ideas (like an AHG).
* A description of each experiment is to be approved at the meeting at which the experiment plan is established. This should include the issues that were raised by other experts when the tool was presented, e.g., interference with other tools, contribution of different elements that are part of a package, etc. The experiment description document should provide the names of individual people, not just company names.
* Software for tools investigated in a CE will be provided in one or more separate branches of the software repository. Each CE will have a “fork” of the software, and within the CE there may be multiple branches established by the CE coordinator. The software coordinator will help coordinate the creation of these forks and branches and their naming. All JVET members will have read access to the CE software branches (using shared read-only credentials; the method for members to obtain the credentials is TBA on the reflector).
* During the experiment, revisions of the experiment plans can be made, but not substantial changes to the proposed technology.
* The CE description must match the CE testing that is done. The CE description needs to be revised if there has been some change of plans.
* The CE summary report must describe any changes that were made in the process of finalizing the CE.
* By the next meeting it is expected that at least one independent cross-checker will report a detailed analysis of each proposed feature that has been tested and confirm that the implementation is correct. Commentary on the potential benefits and disadvantages of the proposed technology in cross-checking reports is highly encouraged. Having multiple cross-checking reports is also highly encouraged (especially if the cross-checking involves more than confirmation of correct test results). The reports of cross-checking activities may (and generally should) be integrated into the CE report rather than submitted as separate documents.

It is possible to define sub-experiments within particular CEs, for example designated as CEX.a, CEX.b, etc., where X is the basic CE number.

As a general rule, it was agreed that each CE should be run under the same testing conditions using one software codebase, which should be based on the group test model software codebase. An experiment is not to be established as a CE unless there is access given to the participants in (any part of) the CE to the software used to perform the experiments.

The general agreed common conditions for single-layer coding efficiency experiments are described in the output document JVET-J1010 (update).

Experiment descriptions should be written in a way such that it is understood as a JVET output document (written from an objective “third party perspective”, not a proponent perspective – e.g. not referring to methods as “improved”, “optimized”, etc.). The experiment descriptions should generally not express opinions or suggest conclusions – rather, they should just describe what technology will be tested, how it will be tested, who will participate, etc. Responsibilities for contributions to CE work should identify individuals in addition to company names.

CE descriptions contain a basic description of the technology under test, but should not contain excessively verbose descriptions of a technology (at least not unless the technology is not adequately documented elsewhere). Instead, the CE descriptions should refer to the relevant proposal contributions for any necessary further detail. However, the complete detail of what technology will be tested must be available – either in the CE description itself or in documents that are referenced in the CE description that are also available in the JVET document archive.

Any technology must have at least one cross-check partner to establish an CE – a single proponent is not enough. It is highly desirable have more than just one proponent and one cross-checker.

Some agreements relating to CE activities were established as follows:

* Only qualified JVET members can participate in an CE.
* Participation in an CE is possible without a commitment of submitting an input document to the next meeting. Participation is requested by contacting the CE coordinator.
* All software, results, and documents produced in the CE should be announced and made available to JVET in a timely manner.
* All substantial communications about a CE, other than logistics arrangements, exchange of data, minor refinement of the test plans, and preparation of documents shall be conducted on the main JVET reflector. In the case that large amounts of data are to be distributed is recommended to send an announcement to the JVET reflector without attaching the materials, and send the materials to those who have requested it directly, or provide a link to it, or upload the data as an input contribution to the next meeting.

General timeline for CEs

T1= 3 weeks after the JVET meeting: To revise the CE description and refine questions to be answered. Questions should be discussed and agreed on JVET reflector. Any changes of planned tests after this time need to be announced and discussed on the JVET reflector.

T2 = Test model SW release + 2 weeks: Integration of all tools into a separate CE branch of the VTM is completed and announced to JVET reflector.

* Initial study by cross-checkers can begin.
* Proponents may continue to modify the software in this branch until T3
* 3rd parties encouraged to study and make contributions to the next meeting with proposed changes

T3: 3 weeks before the next JVET meeting: Any changes to the CE test branches of the software must be frozen, so the cross-checkers can know exactly what they are cross-checking. A software version tag should be created at this time and announced on the JVET reflector. The name of the cross-checkers and list of specific tests for each tool under study in the CE plan description by this time. Full test results must be provided at this time (at least for proposals targeting to be promoted to the draft standard at the next meeting).

CE reports may contain additional information about tests of straightforwared combinations of the identified technologies. Such supplemental testing needs to be clearly identified in the report if it was not part of the CE plan.

New branches may be created which combine two or more tools included in the CE document or the VTM (as applicable). [Search/remove obsolete references to BMS.]

It is not necessary to formally name cross-checkers in the initial version of the CE description document. To adopt a proposed feature at the next meeting, we would like see comprehensive cross-checking done, with analysis that the description matches the software, and recommendation of value of the tool given tradeoffs.

The establishment of a CE does not indicate that a proposed technology is mature for adoption or that the testing conducted in the CE is fully adequate for assessing the merits of the technology, and a favourable outcome of CE does not indicate a need for adoption of the technology.

Draft specification text shall be provided with CE input documents.

CE plans were initially reviewed Thursday 11 Oct 1630 (GJS) and 1800 (J. Boyce); the final review during the meeting was conducted Friday 12 Oct 1100 (GJS).

Lists of participants in CE documents should be pruned to include only the active participants. Read access to software will be available to all members.

## Software development and anchor generation (update)

The planned timeline for software releases was established as follows:

* VTM3.0 will be released by 2018-11-09. VTM3.1 with non-CTC adoptions will be released later.
* Further versions of VTM may be released for additional bug fixing, as appropriate.
* Timeline of 360lib8.0: 1 week after the release of VTM3.0 (2018-11-16). Further versions may be released as appropriate for bug fixing.

# Establishment of ad hoc groups

The ad hoc groups established to progress work on particular subject areas until the next meeting are described in the table below. The discussion list for all of these ad hoc groups was agreed to be the main JVET reflector ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de)).

|  |  |  |
| --- | --- | --- |
| **Title and Email Reflector** | **Chairs** | **Mtg** |
| **Project Management (AHG1)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Coordinate overall JVET interim efforts. * Supervise CE and AHG studies. * Report on project status to JVET reflector. * Provide a report to next meeting on project coordination status. | J.-R. Ohm, G. Sullivan (co-chairs) | N |
| **Draft text and test model algorithm description editing (AHG2)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Produce and finalize JVET-L1001 VVC text specification Working Draft 3. * Produce and finalize JVET-L1002 VVC Test Model 3 (VTM 3) Algorithm and Encoder Description. * Gather and address comments for refinement of these documents. * Coordinate with test model software development AhG to address issues relating to mismatches between software and text. | B. Bross, J. Chen (co-chairs), J. Boyce, S. Kim, S. Liu, Y. Ye (vice-chairs) | N |
| **Test model software development (AHG3)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Coordinate development of test model (VTM) software and associated configuration files. * Produce documentation of software usage for distribution with the software. * Discuss and make recommendations on the software development process. * Propose improvements to the guideline document for developments of the test model software. * Coordinate with AHG on Draft text and test model algorithm description editing (AHG2) to identify any mismatches between software and text, and make further updates and cleanups to the software as appropriate. * Coordinate with AHG6 for integration with 360lib software. | F. Bossen, X. Li, K. Sühring (co-chairs) | N |
| **Test material and visual assessment (AHG4)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Maintain the video sequence test material database for development of the VVC standard. * Identify and recommend appropriate test materials for use in the development of the VVC standard. * Identify missing types of video material, solicit contributions, collect, and make available a variety of video sequence test material. * Evaluate new test sequences, particularly including the material recently submitted by the Blender Foundation / Blender Animation Studio and Twitch. * Propose a new structure for the test sequence repository. * Facilitate availability of viewing equipment and facilities arrangements for the next meeting and pre-meeting testing as feasible. | T. Suzuki (chair), V. Baroncini, R. Chernyak, P. Hanhart, A. Norkin, J. Ye (vice-chairs) | N |
| **Memory bandwidth consumption of coding tools (AHG5)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Develop improved software tools for measuring both average and worst case of memory bandwidth, and provide information for usage of these tools. * Study cache configurations for measuring decoder memory bandwidth consumption. * Identify coding tools in CEs and VTM with significant memory bandwidth impact. * Study the impact of memory bandwidth on specific application cases. | R. Hashimoto (chair), T. Ikai, X. Li, D. Luo, H. Yang, M. Zhou (vice-chairs) | N |
| **360° video conversion software development (AHG6)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Prepare and deliver the 360Lib-8.0 software version and common test condition configuration files according to JVET-L1012. * Generate CTC (PHEC) anchors and PERP results for VTM according to JVET-L1012, and finalize the reporting template for the common test conditions. * Produce documentation of software usage for distribution with the software. | Y. He, K. Choi (co-chairs) | N |
| **Coding of HDR/WCG material (AHG7)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study and evaluate available HDR/WCG test content. * Study objective metrics for quality assessment of HDR/WCG material, including investigation of the correlation between subjective and objective results of the CfP responses. * Compare the performance of the VTM and HM for HDR/WCG content. * Prepare for expert viewing of HDR content at the 13th JVET meeting if feasible. * If feasible, arrange a demonstration event for viewing of JVET-L0205 and JVET-L0245 coded material and possibly other material. * Coordinate implementation of HDR anchor aspects in the test model software with AHG3. * Study additional aspects of coding HDR/WCG content. | A. Segall (chair), E. François, W. Husak, D. Rusanovskyy (vice-chairs) | Y.  Date TBA (likely in Burbank US, or DE, FR, or UK) |
| **360° video coding tools and test conditions (AHG8)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study the effect on compression and subjective quality of different projections formats, resolutions, and packing layouts. * Discuss refinements of common test conditions, test sequences, and evaluation criteria. * Solicit additional test sequences, and evaluate suitability of test sequences on head-mounted displays and normal 2D displays. * Study coding tools dedicated to 360° video, their impact on compression, and implications to the core codec design. * Study the effect of viewport resolution, field of view, and viewport speed/direction on visual comfort. * Study complexity of GPU rendering of projection formats * Study syntax for signalling of projection formats | J. Boyce (chair), K. Choi, P. Hanhart, J.-L. Lin (vice-chairs) | N |
| **Neural networks in video coding (AHG9)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Investigate the benefit of using neural networks in video compression such as CNN loop filter, intra prediction, re-sampling in adaptive resolution coding, and encoder side partition mode decisions. * Investigate the complexity impact of using neural networks in video compression. * Investigate the complexity measurement of neural network coding tools. * Investigate the impact of training materials on the performance of neural network coding tools. * Investigate the impact of the training process on performance and complexity. | S. Liu (chair), B. Choi, K. Kawamura, Y. Li, L. Wang, P. Wu, H. Yang (vice-chairs) | N |
| **Encoding algorithm optimization (AHG10)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study the impact of using techniques such as GOP structures and perceptually optimized adaptive quantization for encoder optimization. * Study the impact of MTS transforms on quantization matrices and the need for default matrices. * Study the impact of adaptive quantization on individual tools in the test model. * Study the quantization adaptation tool in the test model. * Investigate the feasibility of adding a CTC test category in which adaptive quantization is turned on. * Study quality metrics for measuring subjective quality using e.g. the CfP response MOS scores. * Investigate other methods of improving objective and/or subjective quality, including adaptive coding structures, adaptive quantization without signalling, and multi-pass encoding. * Study methods of rate control and their impact on performance, subjective and objective quality. | A. Duenas, A. Tourapis (co-chairs), C. Helmrich, S. Ikonin, A. Norkin, R. Sjöberg, T. Toma (vice-chairs) | N |
| **Screen content coding (AHG11)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Investigate coding tools targeted at screen content in terms of compression benefit and implementation complexity. * Identify test materials and discuss testing conditions for screen content coding. | S. Liu (chair), J. Boyce, A. Filippov, Y.-C. Sun, J. Xu, M. Zhou (vice-chairs) | N |
| **High-level parallelism and coded picture regions (AHG12)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study tile group designs, including rectangular tile groups. * Study flexible (including non-CTU-aligned) tile partitioning including identifying implications on coding tools and implementation. * Study support of independently coded picture regions, including easy rewriting of such regions into a conforming sub-bitstream. * Prepare software and configurations for the test model to facilitate parallel processing tests. * Study the coding efficiency impact of parallel processing and coded picture regions. | T. Ikai (chair), M. M. Hannuksela, R. Sjöberg, R. Skupin, W. Wan, Y.-K. Wang S. Wenger (vice-chairs) | N |
| **Tool reporting procedure (AHG13)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Prepare output document JVET-L1005, which describes the methodology of tool-off testing and a list of tools to be tested by identified testers. * Provide configurations files, bitstreams, and results of the tool-on/tool-off testing. * Use the tool usage counts and memory bandwidth usage to study the decoder complexity of features in on/off testing. * Prepare a report with results of the tests. | W.-J. Chien, J. Boyce (co-chairs), R. Chernyak, K. Choi, R. Hashimoto, Y.**-**W. Huang, S. Liu, D. Luo (vice-chairs) | N |
| **Progressive intra refresh (AHG14)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Define relevant test conditions to evaluate low-latency encoding with progressive intra refresh for random access without intra frames. * Study non-normative ways to produce progressive intra refresh with minimum losses in coding efficiency. * Propose software modifications for integrating encoder-only intra refresh in the VTM model. * Characterize progressive intra refresh performance objectively and subjectively. * Study normative solutions to improve intra refresh performance against encoder-only intra refresh. | J.-M. Thiesse (chair), A. Duenas, K. Kazui, A. Tourapis (vice-chairs) | N |
| **Bitstream decoding properties signalling (AHG15)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study syntax alternatives for interoperability point signalling * Study selection of constraint flags to be included in the VTM and their impact on syntax, semantics, and decoding process | J. Boyce (chair), J. Chen, S. Deshpande, M. Karczewicz, A. Tourapis, Y.-K. Wang, S. Wenger (vice-chairs) | Tel. TBA  (one or two, at least two weeks notice for each) |
| **Implementation studies (AHG16)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study draft and proposed coding tools to identify implementation issues relating to decoder pipelines, decoder throughput, and other aspects of implementation difficulty. * Solicit hardware analysis of complex tools. * Particularly consider intra reconstruction throughput for small blocks. * Provide feedback on potential solutions to address identified issues. | M. Zhou (chair), J. An, E. Chai, K. Choi, S. Ethuraman, T. Hsieh, X. Xiu (vice-chairs) | N |
| **High-level syntax (AHG17)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study NAL unit header, sequence parameter set, picture parameter set, and tile group header syntax designs * Study the proposed picture header designs and alternatives * Study reference picture buffering and list construction * Study random access signalling * Assist in software development and text drafting for the high-level syntax in the VVC design. | R. Sjöberg (chair), S. Deshpande, M. M. Hannuksela, R. Skupin, Y.-K. Wang, S. Wenger (vice-chairs) | N |

# Output documents

The following documents were agreed to be produced or endorsed as outputs of the meeting. Names recorded below indicate the editors responsible for the document production. Where applicable, dates of planned finalization and corresponding parent-body document numbers are also noted.

It was reminded that in cases where the JVET document is also made available as MPEG output document, a separate version under the MPEG document header should be generated. This version should be sent to GJS and JRO for upload.

[JVET-L1000](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4833) Meeting Report of the 12th JVET Meeting [G. J. Sullivan, J.-R. Ohm] (2018-12-31, near next meeting)

Initial versions of the meeting notes (d0 … d8) were made available on a daily basis during the meeting.

[JVET-L1001](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4834) Versatile Video Coding (Draft 3) [B. Bross, J. Chen, S. Liu] [WG 11 [N 18027](http://phenix.it-sudparis.eu/mpeg/doc_end_user/current_document.php?id=64796&id_meeting=176)] (2018-11-23)

(Initial version planned to be made available by 2018-11-02.)

See the list of elements under section 12.6.2, as agreed by the Wed. 18 October plenary.

[JVET-L1002](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4835) Algorithm description for Versatile Video Coding and Test Model 3 (VTM 3) [J. Chen, Y. Ye, S. Kim] [WG 11 [N 18028](http://phenix.it-sudparis.eu/mpeg/doc_end_user/current_document.php?id=64797&id_meeting=176)] (2018-12-14)

(Initial version planned to be made available by 2018-11-09.)

See the list of elements under section 12.6.2, as agreed by the Wed. 18 October plenary.

Remains valid – not updated: [JVET-K1003](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4112) Guidelines for VVC reference software development [K. Sühring] (2018-07-31)

[JVET-L1004](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4836) Algorithm descriptions of projection format conversion and video quality metrics in 360Lib (Version 8) [Y. Ye, J. Boyce] (2018-11-23)

For this output, it was agreed to add discussion of chroma location.

[JVET-L1005](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4837) Methodology and reporting template for coding tool testing [W.-J. Chien and J. Boyce] (2018-10-26)

For this output, it was agreed to remove discussion of BMS, update for tools adopted at the 12th meeting, and update the schedule.

[JVET-L1006](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4838) Methodology and reporting template for neural network coding tool testing [Y. Li, S. Liu] (2018-10-26)

This output was produce to capture aspects specific to enable study of neural network techniques.

[JVET-L1010](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4839) JVET common test conditions and software reference configurations for SDR video [F. Bossen, J. Boyce, X. Li, V. Seregin, K. Sühring] (2018-10-26)

For this output, it was agreed to remove discussion of BMS and to make Class F testing mandatory (but not included in the reported averages).

[JVET-L1011](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4832) JVET common test conditions and evaluation procedures for HDR/WCG video [A. Segall, E. François, S. Iwamura, D. Rusanovskyy] (2018-10-26)

A correction was needed.

[JVET-L1012](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4840) JVET common test conditions and evaluation procedures for 360° video [P. Hanhart, J. Boyce, K. Choi, J.-L. Lin] (2018-10-26)

Aspects include to enable wrap-around MVs for ERP, andupdating to use PHEC as an anchor.

[JVET-L1021](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4826) Description of Core Experiment 1 (CE 1): Partitioning [J. Ma, F. Le Léannec, M. W. Park]

This CE was planned to study L0313 and L0128, which are ways to deal with the intent to enable 64x64 pipeline decoding operation, trying to improve the coding efficiency relative to the current approach.

In the closing review on Friday it was commented that part of L0313 is less consistent with the 64x64 pipeline goal than L0128, and could be more difficult to implement on some hardware architectures. It was agreed to only include the rectangular variant of L0313, not the L-shaped variant, in the testing.

[JVET-L1022](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4828) Description of Core Experiment 2 (CE2): Subblock motion compensation [Y. He, C.-Y. Chen, C.-C. Chen]

This CE was planned to study affine motion, planar MV prediction, subblocks for ATMVP, and related constraints.

It was noted that the draft CE plan contained a large number of subtests, and it was requested for the number to be reduced during the CE plan finalization. It was noted that part of the issue was that the plan included several combinations.

A need for coordination between CE2 and CE4 was identified, as there are some overlapping aspects.

[JVET-L1023](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4819) Description of Core Experiment 3 (CE3): Intra Prediction and Mode Coding [G. Van der Auwera, J. Heo, A. Filippov]

This CE was planned to study about 11 contributed methods relating to intra prediction and intra mode coding.

[JVET-L1024](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4830) Description of Core Experiment 4 (CE4): Inter prediction and motion vector coding [H. Yang, S. Liu, K. Zhang]

This CE was planned to study list derivation, merge, motion vector coding, and inter-prediction-related constraints.

A need for coordination between CE2 and CE4 was identified, as there are some overlapping aspects.

It was asked whether non-adjacent merge candidates should be included in the CE, due to complexity concerns. A proponent said that some versions of this does not require extra memory (either with 8x8 grid or within the current 64x64 region), and suggested to study these versions. The CE finalization will consider this and may remove some subtests.

It was suggested to include some testing of using longer lists of merge candidates. Just increasing the list size of VTM 3 merge mode (currently 6) was suggested to be used as another anchor.

[JVET-L1025](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4827) Description of Core Experiment 5 (CE5): Arithmetic Coding Engine [H. Kirchhoffer, A. Said]

This CE was planned to study alternative arithmetic coding engines and customized window sizes.

It was commented that including the bypass bins in the throughput testing seemed unnecessary and complicates the model. The bypass processing is the same for all cases. It was agreed to remove that aspect.

[JVET-L1026](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4821) Description of Core Experiment 6 (CE6): Transforms and transform signalling [A. Said, X. Zhao]

This CE was planned to study transform core designs, fast transform factorizations, transform signalling, subblock transforms, and secondary transforms.

It was noted that the draft CE plan contained a large number of subtests, and it was requested for the number to be reduced during the CE plan finalization. It was noted that part of the issue was that the plan included several combinations.

[JVET-L1027](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4823) Description of Core Experiment 7 (CE 7): Quantization and coefficient coding [H. Schwarz, M. Coban, C. Auyeung]

This CE was planned to study reducing the number of context coded bins in coefficient coding, and reducing the number of passes.

[JVET-L1028](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4825) Description of Core Experiment 8 (CE8): Screen Content Coding Tools [X. Xu, Y.-H. Chao, Y.-C. Sun, J. Xu]

This CE was planned to study CPR modifications, palette mode modifications, and block-based DPCM.

[JVET-L1029](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4829) Description of Core Experiment 9 (CE9): Decoder-Side Motion Vector Derivation [X. Xiu, S. Esenlik]

This CE was planned to study bidirectional optical flow, bilateral matching and template based matching techniques for DMVR.

[JVET-L1030](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4824) Description of Core Experiment 10 (CE10): Combined and multi-hypothesis prediction [C.-W. Hsu, M. Winken, X. Xiu]

This CE was planned to study OBMC, multiple shape partitions, prediction with more than two hypotheses, local illumination compensation, diffusion filter, and other blending of multiple predictors (if any).

[JVET-L1031](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4831) Description of Core Experiment 11 (CE11): Deblocking [A. Norkin, A. M. Kotra]

This CE was planned to study longer tap-length filters and deblocking on a 4x4 grid.

The number of actual tests was planned to be reduced, relative to the initial presented version.

[JVET-L1032](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4820) Description of Core Experiment 12 (CE12): Mapping functions [E. François, P. Yin]

This CE was planned to include in-loop mapping functions for SDR.

[JVET-L1033](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4818) Description of Core Experiment 13 (CE13): Coding tools for 360° omnidirectional video [P. Hanhart, J.-L. Lin, C. Pujara]

This CE was planned to study changes to in-loop filters, inter prediction, post-filtering, projection rotations and packings.

# Future meeting plans, expressions of thanks, and closing of the meeting

Future meeting plans were established according to the following guidelines:

* Meeting under ITU-T SG 16 auspices when it meets (starting meetings on the Tuesday or Wednesday of the first week and closing it on the Tuesday or Wednesday of the second week of the SG 16 meeting – a total of 6–7.5 meeting days), and
* Otherwise meeting under ISO/IEC JTC 1/SC 29/WG 11 auspices when it meets (starting meetings on the Wednesday or Thursday prior to such meetings and closing it on the last day of the WG 11 meeting – a total of 8.5 meeting days).

In cases where high workload is expected for a meeting, an earlier starting date may be defined.

Some specific future meeting plans (to be confirmed) were established as follows:

* Wed. 9 – Fri. 18 January 2019, 13th meeting under WG 11 auspices in Marrakech, MA.
* Tue. 19 – Wed. 27 March 2019, 14th meeting under ITU-T auspices in Geneva, CH.
* Wed. 3 – Fri. 12 July 2019, 15th meeting under WG 11 auspices in Gothenburg, SE.
* Tue. 1 – Wed. 9 October 2019, 16th meeting under ITU-T auspices in Geneva, CH.

The agreed document deadline for the 13th JVET meeting was planned to be Wednesday 2 January 2019 (a little later than usual due to the proximity of the New Year holiday). Plans for scheduling of agenda items within that meeting remained TBA.

WG 11, the local hosting organization of the MPEG National Body of China, and the supporting organizations of the Macao Convention and Exhibition Association, Huawei, and Zhejiang University were thanked for the excellent hosting and organization of the 12th meeting of the JVET.

Huawei was thanked for providing viewing equipment used during the 12th JVET meeting.

The Blender Foundation / Blender Animation Studio were thanked for providing additional test material for usage in standardization efforts.

The 12th JVET meeting was closed at approximately 1330 hours on Friday 12 October 2018.

# Annex A to JVET report: List of documents

# Annex B to JVET report: List of meeting participants

The participants of the twelfth meeting of the JVET, according to a sign-in sheet circulated during the meeting sessions (approximately 286 people in total), were as follows:

1. Kiyofumi Abe (Panasonic)
2. Jaehoon Ahn (LG Electronics)
3. Yong-Jo Ahn (Digital Insights)
4. Alireza Aminlou (Nokia)
5. Jicheng An (Alibaba)
6. Kenneth Andersson (LM Ericsson)
7. Ichiro Ando (Nikon)
8. Cheung Auyeung (Huawei)
9. Saurav Bandyopadhyay (InterDigital Commun.)
10. Vittorio Baroncini (GBTech)
11. Max Blaeser (RWTH Aachen Univ.)
12. Saverio Blasi (BBC)
13. Philippe Bordes (Technicolor)
14. Frank Bossen (Sharp)
15. Jill Boyce (Intel)
16. Benjamin Bross (Fraunhofer HHI)
17. Wenting Cai (Fujitsu)
18. Eric (Chi W.) Chai (Ubilinx)
19. Yao-Jen Chang (Foxconn)
20. Yung-Hsuan Chao (Qualcomm Tech.)
21. Ching-Yeh Chen (MediaTek)
22. Chun-Chi Chen (Qualcomm Tech.)
23. Fangdong Chen (Hikvision)
24. Huanbang Chen (Huawei)
25. Jianle Chen (Huawei)
26. Jie Chen (Samsung)
27. Lulin Chen (MediaTek)
28. Peisong Chen (Broadcom)
29. Xu Chen (Huawei Tech.)
30. Yucong Chen (Kwai)
31. Roman Chernyak (Huawei)
32. Man-Shu Chiang (MediaTek)
33. Wei-Jing Chien (Qualcomm)
34. Jae Ryun Choe (Hanbat Nat. Univ.)
35. Byeongdoo Choi (Sharp)
36. Haechul Choi (Hanbat Nat. Univ.)
37. Hansol Choi (Kwangwoon Univ.)
38. Jangwon Choi (LG Electronics)
39. Jiun Choi (LG Electronics)
40. Jungah Choi (LG Electronics)
41. Kiho Choi (Samsung Electronics)
42. Narae Choi (Samsung Electronics)
43. Woong Il Choi (Samsung)
44. Tzu-Der Chuang (MediaTek)
45. Takeshi Chujoh (Sharp)
46. Muhammed Coban (Qualcomm)
47. Santiago De Luxán (Fraunhofer HHI)
48. Zhipin Deng (Intel)
49. Sachin Deshpande (Sharp)
50. André Dias (BBC)
51. Jihoon Do (Korea Aerosp. Univ.)
52. Jie Dong (Qualcomm)
53. Andrew Dorrell (CiSRA / Canon)
54. Virginie Drugeon (Panasonic)
55. Amith DSouza (Samsung)
56. Hilmi Egilmez (Qualcomm Tech.)
57. Semih Esenlik (Huawei)
58. Alexey Filippov (Huawei)
59. Chad Fogg (MovieLabs)
60. Edouard François (Technicolor)
61. Tianliang Fu (Peking Univ.)
62. Shigeru Fukushima (JVC Kenwood)
63. Arild Fuldseth (Cisco Systems Norway)
64. Alexandre Gabriel (TNO)
65. Raj Narayanan Gadde (Samsung)
66. Frank Galpin (Technicolor)
67. Han Gao (Huawei)
68. Min Gao (Tencent)
69. Wen Gao (Harmonic)
70. Ramin Ghaznavi (Nokia)
71. Dan Grois (Comcast)
72. Dae-hyeok Gwon (Hanbat Univ.)
73. Woowoen Gwun (Kyung Hee Univ.)
74. Soo-Chul Han (Vidyo)
75. Philippe Hanhart (InterDigital Commun.)
76. Miska Hannuksela (Nokia)
77. Ryoji Hashimoto (Renesas)
78. Tomonori Hashimoto (Sharp)
79. Yuwen He (InterDigital Commun.)
80. Hendry (Huawei)
81. Félix Henry (Orange)
82. Jin Heo (LG Electronics)
83. Tobias Hinz (Fraunhofer HHI)
84. Shi-Ta Hsiang (MediaTek)
85. Ted Hsieh (Qualcomm Tech.)
86. Chih-Wei Hsu (MediaTek)
87. Nan Hu (Qualcomm Tech.)
88. Yu-Wen Huang (MediaTek)
89. Chao-Hsiung Hung (Qualcomm)
90. Junyon Huo (Xidian Univ.)
91. Atsuro Ichigaya (NHK (Japan Broadcasting Corp.))
92. Tomohiro Ikai (Sharp)
93. Masaru Ikeda (Sony)
94. Sergey Ikonin (Huawei)
95. Sennybin Im (Royal Patent Law)
96. Shunsuke Iwamura (NHK (Japan Broadcasting Corp.))
97. Hyeongmoon Jang (LG Electronics)
98. Byeungwoo Jeon (Sungkyunkwan Univ. (SKKU))
99. Yongwook Jeon (LG Electronics)
100. Seungsoo Jeong (Samsung)
101. Wook Je Jeong (Chips & Media)
102. Hong-Jheng Jhu (Foxconn)
103. Wonhee Jo (Kwangwoon Univ.)
104. Jaehong Jung (Gaudi Audio Lab)
105. Jung Won Kang (Electronics and Telecom Research Institute (ETRI))
106. Marta Karczewicz (Qualcomm Tech.)
107. Yusuke Kato (Panasonic)
108. Kei Kawamura (KDDI)
109. Kimihiko Kazui (Fujitsu Labs)
110. Steve Keating (Sony)
111. Michel Kerdranvat (Technicolor)
112. Yoshitaka Kidani (KDDI)
113. Dae Yeon Kim (Chips & Media)
114. Dongcheol Kim (Wilus)
115. Hanah Kim (Wilus)
116. Hyung Kim (Cisco)
117. Hyunho Kim (Korea Aerosp. Univ.)
118. Jae-Gon Kim (Korea Aerosp. Univ.)
119. Jaeil Kim (SK Telecom)
120. Seung-Hwan Kim (LG Electronics)
121. Tea Hyun Kim (Kyung Hee Univ.)
122. Heiner Kirchhoffer (Fraunhofer HHI)
123. Geonjung Ko (Wilus)
124. Kenji Kondo (Sony)
125. Konstantinos Konstantinides (Dolby Labs)
126. Moonmo Koo (LG Electronics)
127. Anand Meher Kotra (Huawei)
128. Gosala Kulupana (BBC)
129. Jin Sam Kwak (Wilus)
130. Jani Lainema (Nokia)
131. Fabrice Le Léannec (Technicolor)
132. Bumshik Lee (Chosun Univ.)
133. Dae Young Lee (Kyung Hee Univ.)
134. Geonwon Lee (Sejong Univ.)
135. Hahyun Lee (Electronics and Telecom Research Institute (ETRI))
136. Jaeho Lee (LG Electronics)
137. Jaeyoung Lee (LG Electronics)
138. Jinho Lee (Electronics and Telecom Research Institute (ETRI))
139. Jong-Seok Lee (Kwangwoon Univ.)
140. Sunyoung Lee (Pixtree)
141. Wooju Lee (Kwangwoon Univ.)
142. Ya-Hsuan Lee (MediaTek)
143. Shawmin Lei (MediaTek)
144. Zhijun Lei (Intel)
145. Guichun Li (Tencent)
146. Ling Li (LG Electronics)
147. Tim Li (Foxconn)
148. Xiang Li (Tencent)
149. Yiming Li (Wuhan Univ.)
150. Yue Li (Univ. Sci. & Tec. China)
151. Ru Ling Liao (Panasonic)
152. Chongsoon Lim (Panasonic)
153. Jaehyun Lim (LG Electronics)
154. Jeong Yun Lim (Kaon Media)
155. Kukil Lim (Wilus)
156. Sung-Chang Lim (Electronics and Telecom Research Institute (ETRI))
157. Ching-Chieh Lin (ITRI Intl.)
158. Jian-Liang Lin (MediaTek)
159. Po-Han Lin (ITRI Intl.)
160. Yongbing Lin (Huawei Tech.)
161. Zhi-Yi Lin (MediaTek)
162. Hongbin Liu (Bytedance)
163. Shan Liu (Tencent)
164. Zizheng Liu (Wuhan Univ.)
165. Jian Lou (Alibaba)
166. Jiancong Luo (InterDigital Commun.)
167. Jackie Ma (Fraunhofer HHI)
168. Xiang Ma (Huawei)
169. Ken McCann (Zetacast)
170. Sean McCarthy (Dolby)
171. Akira Minezawa (Mitsubishi Electric)
172. Kiran Misra (Sharp)
173. Hyeonchul Moon (Korea Aerosp. Univ.)
174. Elie Mora (Ateme)
175. Karsten Müller (Fraunhofer HHI)
176. Taeyoung Na (SK Telecom)
177. Junghak Nam (LG Electronics)
178. Shimpei Nemoto (NHK)
179. Tung Nguyen (Fraunhofer HHI)
180. Andrey Norkin (Netflix)
181. Jens-Rainer Ohm (RWTH Aachen Univ.)
182. Patrice Onno (Canon Research Centre France)
183. Dohyeon Park (Korea Aerosp. Univ.)
184. Dongyun Park (LG Electronics)
185. Jae Yoon Park (SKKU Univ.)
186. Jun-Taek Park (Kwangwoon Univ.)
187. Min Woo Park (Samsung Electronics)
188. Minsoo Park (Samsung Electronics)
189. Naeri Park (LG Electronics)
190. Seanae Park (KWU)
191. Martin Pettersson (Ericsson)
192. Jonathan Pfaff (Fraunhofer HHI)
193. Pierrick Philippe (Orange Labs FT)
194. Yinji Piao (Samsung)
195. Fangjun Pu (Dolby Labs)
196. Chirag Pujara (Samsung)
197. Fabien Racapé (Technicolor)
198. Adarsh Krishnan Ramasubramonian (Qualcomm Tech.)
199. Justin Ridge (Nokia)
200. Christopher Rosewarne (CiSRA / Canon)
201. Vasily Rufitskiy (Huawei)
202. Gahyun Ryu (Samsung)
203. Jonatan Samuelsson (Divideon)
204. Yago Sanchez De La Fuente (Fraunhofer HHI)
205. Johannes Sauer (IENT)
206. Thomas Schierl (Fraunhofer HHI)
207. Heiko Schwarz (Fraunhofer HHI)
208. Andrew Segall (Sharp)
209. Vadim Seregin (Qualcomm)
210. Sriram Sethuraman (Ittiam)
211. Karl Sharman (Sony Europe Broad. & Prof. Research Labs)
212. Masato Shima (Canon)
213. Donggyu Sim (Kwangwoon Univ.)
214. Rickard Sjöberg (Ericsson)
215. Robert Skupin (Fraunhofer HHI)
216. Yumi Sohn (Samsung)
217. Timofey Solovyev (Huawei)
218. Juhyung Son (Wilus)
219. Sehoon Son (Pixtree)
220. Peikang Song (Apple)
221. Benno Stabernack (Fraunhofer HHI)
222. Jacob Ström (Ericsson)
223. Shiori Sugimoto (NTT)
224. Jong-Yeul Suh (LG Electronics)
225. Sungsam Suh (LG Electronics)
226. Karsten Sühring (Fraunhofer HHI)
227. Gary Sullivan (Microsoft)
228. Yu-Chen Sun (Alibaba)
229. Teruhiko Suzuki (Sony)
230. Anish Tamse (Samsung)
231. Han Boon Teo (Panasonic)
232. Jean-Marc Thiesse (Vitec)
233. Tadamasa Toma (Panasonic)
234. Alexandros Tourapis (Apple)
235. Yi-Ting Tsai (ITRI)
236. Yi-Shin Tung (ITRI USA / MStar Semi.)
237. Kyohei Unno (KDDI)
238. Geert Van der Auwera (Qualcomm)
239. Shuai Wan (NPU Univ.)
240. Wade Wan (Broadcom)
241. Biao Wang (Huawei)
242. Li Wang (Hikvision)
243. Mingze Wang (Northwestern Poly. Univ.)
244. Xianglin Wang (Kwai)
245. Ye-Kui Wang (Huawei)
246. Xing Wen (Kwai)
247. Stephan Wenger (Tencent)
248. Martin Winken (Fraunhofer HHI)
249. Dongjae Won (Sejong Univ.)
250. Samuel Wong (Intel)
251. Ping Wu (ZTE UK)
252. Xiaoyu Xiu (InterDigital Commun.)
253. Jizheng Xu (Bytedance)
254. Lidong Xu (Intel)
255. Liying Xu (Hikvision)
256. Xiaozhong Xu (Tencent)
257. Ning Yan (USTC)
258. Haitao Yang (Huawei Tech.)
259. Johnny Yang (Foxconn)
260. Jie Yao (Fujitsu R&D Center)
261. Yukinobu Yasugi (Sharp)
262. Chang-Hao Yau (ITRI international)
263. Yan Ye (InterDigital Commun.)
264. Peng Yin (Dolby Labs)
265. Sunmi Yoo (LG Electronics)
266. Yong-uk Yoon (Korea Aerosp. Univ.)
267. Grace Yu (Intel)
268. Quanhe Yu (Huawei)
269. Yuangfang Yu (Oppo)
270. Weimin Zeng (Ubilinx)
271. Kai Zhang (Bytedance)
272. Li Zhang (Bytedance)
273. Na Zhang (Huwei)
274. Wenhao Zhang (Hulu)
275. Xiang Zhang (Peking Univ.)
276. Yan Zhang (Qualcomm)
277. Jie Zhao (LG Electronics)
278. Qun Zhao (Xiaomi)
279. Xin Zhao (Tencent)
280. Yin Zhao (Huawei)
281. Jianhua Zheng (Huawei Tech.)
282. Xiaozhen Zheng (DJI)
283. Juejia Zhou (Xiaomi)
284. Minhua Zhou (Broadcom)
285. Tianyang Zhou (Sharp)
286. Jian Qing Zhu (Fujitsu R&D Center)

1. For the Caminandes video 8K resolution 3D 360° renderings are also available for some scenes. An example can be seen here: <https://www.youtube.com/watch?v=uvy--ElpfF8> [↑](#footnote-ref-2)