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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, 03–12 Oct. 2018 | Document: JVET-L\_Notes\_d4 |

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| *Title:* | **Meeting Report of the 12th meeting of the Joint Video Experts Team (JVET), Macao, CN, 3–12 October 2018** | | |
| *Status:* | Report document from chairs of JVET | | |
| *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 03 October 2018. Meeting sessions were held on all days (including weekend days) until the meeting was closed at approximately XXXX hours on Friday 12 October 2018. Approximately XXX 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 draft text and VTM, and plan next steps for further investigation of candidate technology towards the formal standard development.

The JVET produced XX output documents from the meeting (update):

* 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

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

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).

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

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: JVET-L0XXX, … .

“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 without modification.

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 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 0900–2000+ 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 (inter prediction) 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–XXXX JCT-VC opening plenary
  + 1400–XXXX Plenary (chaired by GJS & JRO)
* Sun. 7 October, 5th day
  + XXXX–XXXX Plenary (chaired by GJS & JRO)
* Mon. 8 October, 6th day
  + 0900–1300 WG 11 parent-body opening plenary
  + XXXX–XXXX Joint meeting
* Tue. 9 October, 7th day
* Wed. 10 October, 8th day
  + 0900–1100 WG 11 parent-body mid-week plenary
* Thu. 11 October, 9th day
* Fri. 12 October, 10th day
  + 1400–2000 WG 11 parent-body closing plenary

## Contribution topic overview (update)

The approximate subject categories and quantity of contributions per category for the meeting were summarized as follows:

* 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
  + CE1: Partitioning (6) (section 6.1) (Track A)
  + CE2: Loop filters (7) (section 6.2) (Track B)
  + 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)
  + 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)
  + 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)
  + 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)
  + 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)
  + CE10 related – Combined and multi-hypothesis prediction (2) (section 7.10) (Track B)
  + 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 7.17) (Track B)
  + Other (15) (section 7.18) (Track A)
* Complexity analysis and reduction (4) (section 8) (Track A)
* Encoder optimization (3) (section 9) (Track A)
* Metrics and evaluation criteria (2) (section 10) (TrackA)
* Joint meetings, plenary discussions, BoG reports, Summary of actions (section 11)
* Project planning (section 12)
* Establishment of AHGs (section 13)
* Output documents (section 14)
* Future meeting plans and concluding remarks (section 15)

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. Revisit for that.
* 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

Table 1 and Table 2 are for the projection formats comparison using VTM-2.0.1 and BMS-2.1 according to 360o video CTC (JVET-K1012). Table 1 lists the VTM-2.0.1 CMP coding performance compared to VTM-2.0.1 PERP coding. Table 2 compares the BMS-2.1 CMP coding with BMS-2.1 PERP coding. Table 3 and Table 4 are for VTM-2.0.1 and BMS-2.1 comparison under PERP and CMP projection formats. Table 5 and Table 6 are for VTM-2.0.1 and HM-16.16 comparison under PERP and CMP projection formats.

**Table 1. 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% |

**Table 2. 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% |

**Table 3. 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% |

**Table 4. 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% |

**Table 5. 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% |

**Table 6. 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 recommends:

* 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 neighbors [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 updated 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 Signaling 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 signaling, 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 (X)

## Software development (1)

[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)]

## Common test conditions (X)

## Coding studies (1)

[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)]

# 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] [miss]

# 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 described in [2] can be categorized in three categories:

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

Overall results of all Sub-CEs: [Ed. This is a picture!]



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 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 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 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 signaling 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 signaling, 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 action).

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 action 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 action.
* 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 replaced with shifts (2.5.1), some extra work in 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 action.
* 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 (37)

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 Signaling** | **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

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| **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) |

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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** |
| 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:

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| **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. Revisit.

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 neighboring 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 neighboring 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 neighboring 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 neighboring 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. Revisit: B. Bross to confirm.

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. Revisit: B. Bross to confirm.

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 neighbor-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 Neighbor LM – extends MMLM by using samples from left neighbor, above neighbor, 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 neighbors

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. Revisit: B. Bross to confirm.

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 neighbors; 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 signaling 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 signaling 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 neighbors; 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 neighbors; 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 signaling 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 signaling 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 neighbors; 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:

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **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:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Max number of neighbors 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) to study the two proposals (including spec text) and suggest a candidate for adoption. Revisit.

[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 neighbor-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]

TBP

## 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% |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **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: 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 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **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 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **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 action

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 action.

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 action.

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 action.

*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).

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 action.

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 action 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 improved affine and planar, adding about 0.3% above the improved affine. Since that is small, no action, pending resolving other matters first.

*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 |

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **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 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.
* 4.4.10, 4.4.13, 4.4.14 not showing significant gain; no action.

*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 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **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)

Revisit 4.5.1 after testing with MMVD.

More in CE to finish.

*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 action taken on these.

*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 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **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 action was taken on this.

[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] [miss]

[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-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] [miss]

[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] [miss]

[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] [miss]

[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] [miss]

[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-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]

## CE5: Arithmetic coding engine (11)

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.

Revisit after BoG report.

[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-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]

[JVET-L0617](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4730) Crosscheck of JVET-L0115 (CE5: Per-context CABAC initialization with double windows (Test 5.1.6)) [T.-D. Chuang (MediaTek)] [late] [miss]

[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, Jan Stegemann, D. Marpe, H. Schwarz, T. Wiegand (HHI)] [late]

## CE6: Transforms and transform signalling (19)

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 signaling 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)

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. Revisit.

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 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.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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 signaling | 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.

|  |  |  |  |
| --- | --- | --- | --- |
| 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) |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **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 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. Revisit.

Solution 6.2.2x is not attractive in terms of runtime.

CE6-2.3 a/b:

•NSST based on explicit signaling, flag and index

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **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 signaling 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-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 [Ed. This table is a picture!]



CE8 test results against VTM+CPR anchor



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 continue / revisit / conclusion after reviewing non-CE contributions.

[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] [miss]

## 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 neighbor 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 neighboring 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 this report.

*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 hypothesis (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. Revisit for test results on that.

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%. 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. Revisit for test results on that.

It was remarked that there is likely to be some interaction with generalized B (~0.8% for RA).

[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] [miss]

[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] [miss]

[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)]

[JVET-L0524](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4630) Cross-check report of CE10.1.3 [B. Choi (??)] [late] [miss]

## CE11: Deblocking (20)

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

[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]

[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] [miss]

[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. Revisit: Report results of viewing

Revisit: CE12-5 still to be reviewed

[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] [miss]

## 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 neighbors (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 neighbors (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 neighbors, 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 XXday XX Oct XXXX–XXXX (chaired by XXX).

[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]

[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]

[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 XXday XX Oct XXXX–XXXX (chaired by XXX).

[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]

[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 (27)

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

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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]

[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]

[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] [miss]

[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] [miss]

[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] [miss]

## CE2 related – Adaptive loop filter (4)

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

[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)]

[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)]

[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]

## CE3 related – Intra prediction and mode coding (42)

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

[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)]

[JVET-L0498](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4604) Crosscheck for L0053 (CE3-related: Chroma DM modification) [?? (??)][late] [miss]

[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)]

[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] [miss]

[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)]

[JVET-L0499](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4605) Crosscheck for JVET-L0087 (CE3-related: Boundary PDPC) [?? (??)] [late] [miss]

[JVET-L0107](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4188) Non-CE3: CCLM Performance Of Extended Neighboring Region [S. Wan (NPU), J.-Y. Huo, X.-Y. Chai, Y.-Z. Ma (Xidian Univ.), Y.-F. Yu, Y. Liu (OPPO)]

[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)]

[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)]

[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)]

[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)]

[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] [miss]

[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)]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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)]

[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)]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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)]

[JVET-L0520](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4626) Crosscheck for JVET-L0381 [Hendry (Huawei)] [late] [miss]

[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] [miss]

[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]

[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] [miss]

[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] [miss]

[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]

## CE4 related – Inter prediction and motion vector coding (104)

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 (??)] [late] [miss]

[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] [miss]

[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] [miss]

[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] [miss]

[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) [?? (Huawei)] [late] [miss]

[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] [miss]

[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] [miss]

[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] [miss]

[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] [miss]

[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] [miss]

[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 (??)] [late] [miss]

[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] [miss]

[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] [miss]

[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] [miss]

[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] [miss]

[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] [miss]

[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] [miss]

[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] [miss]

[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 [?? (??)] [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] [miss]

[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] [miss]

[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] [miss]

[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] [miss]

[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-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] [miss]

[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-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] [miss]

[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] [miss]

[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] [miss]

[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 (??)] [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] [miss]

[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)]

[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] [miss]

[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] [miss]

[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] [miss]

[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] [miss]

[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-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] [miss]

[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] [miss]

[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] [miss]

## CE5 related – Arithmetic coding engine (6)

Contributions in this category were discussed XXday XX Oct XXXX–XXXX (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)]

[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] [miss]

[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)]

[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] [miss]

[JVET-L0552](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4661) Training initial CABAC states [F. Bossen (Sharp)] [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]

## CE6 related – Transforms and transform signalling (26)

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

[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)]

[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] [miss]

[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)]

[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] [miss]

[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]

[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)]

[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)]

[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-L0153](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4234) CE6-related: NSST modification for wide angle intra prediction [M. Koo, M. Salehifar, J. Lim, S. Kim (LGE)]

[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)]

[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)]

[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)]

[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] [miss]

[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)]

[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)]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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]

[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]

## CE7 related – Quantization and coefficient coding (21)

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

[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)]

[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] [miss]

[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)]

[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) [?? (??)] [late] [miss]

[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)]

[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)]

[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] [miss]

[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)]

[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)]

[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] [miss]

[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)]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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)]

[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).

[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)]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[JVET-L0626](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4739) Cross-check of JVET-L0299 [?? (??)] [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)]

## CE9 related – Decoder-side motion vector derivation (22)

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

### Decoder motion vector refinement

[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)]

[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] [miss]

[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]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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 (??)] [late] [miss]

[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)]

[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]

### 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 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.

TBP.

[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]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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)]

[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)]

[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] [miss]

## CE11 related – Deblocking (12)

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

[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] [miss]

[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] [miss]

[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)]

[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-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] [miss]

[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)]

[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] [miss]

[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] [miss]

[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 neighbors [Xuchang Huangfu, Yule Sun, Lu Yu (Zhejiang Univ.) [late]

## CE14 related – Post-reconstruction filtering (6)

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

[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)]

[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) [?? (Huawei)] [late] [miss]

[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] [miss]

[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)]

[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] [miss]

[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]

## CE15 related – Palette mode (10)

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

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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 (??)] [late] [miss]

[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)]

[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] [miss]

[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]

[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] [miss]

## NN technology related (3)

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

[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)]

[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] [miss]

[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)]

## Screen content tools (2)

[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)]

[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] [miss]

## 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 H.265, scope is coded video sequence
* (Proposal) Picture Parameter Set (PPS) similar in functionality as in H.265, 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)

[JVET-L0042](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4123) Example restriction flags for VVC [J. Samuelsson (Divideon)]

[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)]

[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)]

[JVET-L0270](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4365) Suggested restriction flag criteria [J. Samuelsson (Divideon)]

### 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. 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 CTUs boundaries in a picture might not be at CTU boundaries in the reference pictures.

Revisit for further discussion.

[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 signaling. The proposed approach includes signaling 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 signaling consists of signaling of a tile set identifier and entry point signaling 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 [Stephan Wenger (??)]

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.

Decision: 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 with a more\_data\_in\_group\_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.

Revisit to double.

Various aspects – potentially rectangular shape, potentially non-grid layouts, etc., TBD.

This is just a starting point – the raster order aspect has no presumptive status.

Revisit discussion of starting point for syntax design. See the L0114 questions.

### Reference picture management (9)

[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)]

[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] [miss]

[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-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)]

[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] [miss]

[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)]

[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)]

[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]

[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]

### Intra refresh (3)

[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)]

[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]

[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]

[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] [miss]

### 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)]

[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)]

## Other (15)

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

[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] [miss]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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)]

[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] [miss]

[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] [miss]

[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)]

[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-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]

[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]

# Complexity analysis and reduction (4)

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

[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] [miss]

[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]

# Encoder optimization (3)

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

[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)]

[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)]

[JVET-L0610](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4723) Crosscheck of JVET-L0241 [J. Chen (Samsung)] [late] [miss]

# Metrics and evaluation criteria (2)

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

[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)]

[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)]

[Add abstract - TBP]

No test results were provided in the contribution. Some test results, e.g., VTM vs. HM were requested.

# Withdrawn (24)

JVET-L0067 Withdrawn

JVET-L0069 Withdrawn

JVET-L0200 Withdrawn

JVET-L0294 Withdrawn

JVET-L0303 Withdrawn

JVET-L0356 Withdrawn

JVET-L0432 Withdrawn

JVET-L0433 Withdrawn

JVET-L0434 Withdrawn

JVET-L0435 Withdrawn

JVET-L0436 Withdrawn

JVET-L0437 Withdrawn

JVET-L0438 Withdrawn

JVET-L0439 Withdrawn

JVET-L0440 Withdrawn

JVET-L0441 Withdrawn

JVET-L0442 Withdrawn

JVET-L0432 Withdrawn

JVET-L0443 Withdrawn

JVET-L0444 Withdrawn

JVET-L0445 Withdrawn

JVET-L0446 Withdrawn

JVET-L0447 Withdrawn

JVET-L0589 Withdrawn

# Plenary meetings, joint Meetings, BoG Reports, and Summary of Actions Taken

## Plenary meeting XXday XX Oct XXXX

## …

## Closing plenary sessions

## Joint meetings

## BoGs (XX)

## 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.

### 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)

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 should have a maximum of 3 coordinators. The role of CE coordinators is again clarified. It is not necessary that each sub-CE has an own coordinator. People in sub-CEs should communicate with each other about how to compare if each other and agree on a compiled version of their part before sending it to the overall 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 Thursday 11 Jan. 2018.

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 at XXday XX October afternoon.

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 can obtain read access to the CE software branches.
* 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 company proponent perspective – e.g. 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.

T2 = Test model SW release + 2 weeks: Integration of all tools into a separate CE branch of the VTM or BMS (as relevant) 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/BMS (as applicable).

It is not necessary to formally name cross-checkers in the initial version of the CE 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.

[Add a note that draft specification text shall be provided with CE input documents.]

## Software development and anchor generation (update)

The planned timeline for software releases was established as follows:

* VTM2.0 will be released by 2018-08-15. This version will include all adoptions necessary for CTC. By the same time, also an implementation of BMS2.0 configuration (with only VTM adoptions) will be provided in a separate branch. BMS2.1 with BMS-only adoption will be released by 2018-08-31. VTM2.1 with non-CTC adoptions will be released later.
* Further versions of VTM may be released for additional bug fixing, as appropriate.

Timeline of 360lib7.0: 1 week after the release of VTM1.0 (2018-08-22). 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 | 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-K1001 VVC text specification Working Draft 2. * Produce and finalize JVET-K1002 VVC Test Model 2 (VTM 2) 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) and benchmark set (BMS) software based on the NextSoftware package and release software packages with associated configuration files (repository to be announced via reflector). * 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, and prepare for the visual assessment and availability of viewing equipment in the next meeting. * Suggest new structure for sequence repository … | V. Baroncini, R. Chernyak, P. Hanhart, A. Norkin, T. Suzuki, J. Ye (co-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, VTM, and BMS with significant memory bandwidth impact. * Study the impact of memory bandwidth on specific application cases. | R. Hashimoto (chair), Y. He, T. Ikai, X. Li, 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-7.0 software version and common test condition configuration files according to JVET-K1012. * Generate CTC VTM and BMS anchors according to JVET-K1012, and finalize the reporting template for the common test conditions. * Produce documentation of software usage for distribution with the software. | Y. He and 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, BMS, and HM for HDR/WCG content. * Prepare for expert viewing of HDR content at the 12th JVET meeting. * 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) | N |
| **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 optimizations (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 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 and A. Tourapis (co-chairs), C. Helmrich, S. Ikonin, A. Norkin, R. Sjöberg (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, 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 high-level parallelism techniques. * Study concepts and proposed methods of representation of coded picture regions such as tiles and slices. * Study usage and additional functionalities for coded regions that may be beneficial beyond what has been done in existing standards * 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. Coban, M. M. Hannuksela, H. M. Jang, R. Sjöberg, R. Skupin, Y.-K. Wang (vice-chairs) | N |
| **Tool reporting procedure (AHG13)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Prepare output document JVET-K1005, which describes the methodology of tool-on/tool-off testing, provides a reporting template, 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. He, Y.**-**W. Huang, S. Liu (vice-chairs) | N |
| **Low-latency random access (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 and BMS 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  (approx. monthly, 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. * Provide feedback on potential solutions to address identified issues. | M. Zhou (chair), E. Chai, K. Choi, S. Ethuraman, O. Hugosson, T. Hsieh, X. Xiu (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-K1000](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4116) Meeting Report of the 11th JVET Meeting [G. J. Sullivan, J.-R. Ohm] (2018-09-15, near next meeting)

(Initial versions of the meeting notes (d0 … d8) were made available on a daily basis during the meeting.)

[JVET-K1001](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4114) Versatile Video Coding (Draft 2) [B. Bross, J. Chen, S. Liu] [WG11 N17732] (2018-08-31)

(Initial version planned to be made available by 2018-08-10.)

See list of elements under section 11.6.2, as agreed by Wed. 18 plenary.

[JVET-K1002](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4117) Algorithm description for Versatile Video Coding and Test Model 2 (VTM 2) [J. Chen, Y. Ye, S. Kim] [WG11 N17733] (2018-08-31)

(Initial version planned to be made available by 2018-08-10.)

See list of elements under section 11.6.2, as agreed by Wed. 18 plenary.

[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-K1004](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4118) Algorithm descriptions of projection format conversion and video quality metrics in 360Lib Version 7 [Y. Ye, J. Boyce] (2018-08-31)

(Identifying as version number 7 to match the software version, although the previous issued document (JVET-H1004) was identified as version 5.)

See list of elements under section 11.6.4, as agreed by the Wed. 18 July plenary.

[JVET-K1005](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4115) Methodology and reporting template for tool testing [AHG13 chairs] (2018-07-27)

[JVET-K1010](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4119) JVET common test conditions and software reference configurations for SDR video [F. Bossen, J. Boyce, X. Li, V. Seregin, K. Sühring] (2018-07-31)

[JVET-K1011](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4120) JVET common test conditions and evaluation procedures for HDR/WCG video [A. Segall, E. François, D. Rusanovskyy] (2018-07-31)

[JVET-K1012](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4113) JVET common test conditions and evaluation procedures for 360° video [P. Hanhart, J. Boyce, K. Choi] (2018-07-31)

For CEs, individual CEs may determine whether testing relative to the BMS is necessary or not. [Move note to a general section.]

[JVET-K1021](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4103) Description of Core Experiment 1 (CE 1): Partitioning [J. Ma, F. Le Léannec, M. W. Park]

Discussion Monday 1830 (GJS & JRO)

* Boundary handling
* Implementation-friendly modifications (e.g., 64x64 pipeline friendly)
* Separate tree for intra regions in inter slices

(Initial version presented Wednesday 1200 (GJS & JRO.)

Discussion - the testing is expected to consider alternative content and variations of test conditions to try to better measure the impact for intra CTUs in inter slices.

[JVET-K1022](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4101) Description of Core Experiment 2 (CE2): Adaptive Loop Filter [V. Seregin, C.-Y. Chen]

Discussion Monday 1840 (GJS & JRO)

* ALF (filter shapes, CTU-based, filter parameter coding, classification, low-latency aspects) []

(Initial version presented Wednesday 1230 (GJS & JRO.)

Some suggested additional things to test may be considered in finalization.

It was agreed during the presentation that no more granular classification finer than 4x4 should be used, as the main complexity impact is switching of the filters, not the classification itself.

[JVET-K1023](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4108) Description of Core Experiment 3 (CE3): Intra Prediction and Mode Coding [G. Van der Auwera, J. Heo, A. Filippov]

Discussion Monday 1850 (GJS & JRO)

* Multiple reference lines
* Interpolation
* Line-based prediction
* Nonlinear weighted intra prediction
* Modified cross-component prediction
* Intra mode coding (e.g., 6 MPM)
* Bidirectional prediction

(Initial version presented Wednesday 1240 (GJS & JRO.)

It was commented that it may be desirable to reduce the number of variations to test.

It was commented that, in the finalization of the plans, it should be considered how to ensure that differences in encoder search techniques and search exhaustiveness are not causing the differences in measured compression performance, e.g. by restricting the number of candidates checked.

[JVET-K1024](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4099) Description of Core Experiment 4 (CE4): Inter prediction and motion vector coding [H. Yang, S. Liu, K. Zhang]

Discussion Monday 1900 (GJS & JRO)

* Merging (affine & non-affine)
* Other affine aspects?
* Padding
* MVD coding
* Illumination compensation
* Motion field compression

(Initial version presented Wednesday 1310 (GJS & JRO.)

[JVET-K1025](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4102) Description of Core Experiment 5 (CE5): Arithmetic Coding Engine [H. Kirchhoffer, A. Said]

Discussion Monday 1910 (GJS & JRO)

* Table-based probability estimation, single & double window, custom window size

(Initial version presented Wednesday 1255 (GJS & JRO.)

The primary comparison reference in the test will be the BMS CABAC engine.

[JVET-K1026](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4105) Description of Core Experiment 6 (CE6): Transforms and transform signalling [A. Said, X. Zhao]

Discussion Monday 1920 (GJS & JRO)

* Primary transform (factorization, precision, selection of the transform, spatial coverage of transform, additional or alternative transform types, handling of chroma)
* Secondary transform

(Initial version presented Wednesday 1320 (GJS & JRO.)

[JVET-K1027](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4104) Description of Core Experiment 7 (CE 7): Quantization and coefficient coding [H. Schwarz, M. Coban, C. Auyeung]

Discussion Monday 1930 (GJS & JRO)

* Context selection
* Reduced number of context models
* Reduced number of context-coded bins
* Alternative state machine dependent quantization
* Scanning order
* Modified residual sign prediction
* Spatial-domain residual scaling

(Initial version presented Wednesday 1330 (GJS & JRO.)

[JVET-K1028](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4098) Description of Core Experiment 8 (CE8): Current Picture Referencing [X. Xu, K. Müller, L. Wang]

Discussion Monday 1940 (GJS & JRO)

* Constraints
* Template matching

(Initial version presented Wednesday 1340 (GJS & JRO.)

[JVET-K1029](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4107) Description of Core Experiment 9 (CE9): Decoder-Side Motion Vector Derivation [S. Esenlik, Y. W. Chen, F. Chen]

Discussion Monday 1945 (GJS & JRO)

* DMVR interpolation filters, padding, search range, partial usage of refined MVs
* Matching method

(Initial version presented Wednesday 1345 (GJS & JRO.)

It was commented that the use of SIMD optimization in this test might affect the ability to use the runtime as an approximation of the complexity impact of the feature (since the rest of the design does not use such low-level optimization). It would be desirable to try to take this into account in the work.

BIO will not be tested in this CE.

[JVET-K1030](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4111) Description of Core Experiment 10 (CE10): Combined and multi-hypothesis prediction [C.-W. Hsu, M. Winken, X. Xiu]

Discussion Monday 1955 (GJS & JRO)

* OBMC, non-rectangular partitions, diffusion filtering, prediction with more than two hypotheses, other blending of multiple predictors

(Initial version presented Wednesday 1350 (GJS & JRO.)

It was requested that test cases should include testing the tools with uni prediction.

[JVET-K1031](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4106) Description of Core Experiment 11 (CE11): Deblocking [A. Norkin, A. M. Kotra]

Discussion Monday (GJS & JRO)

* longer filters,
* 4x4 deblocking, …

(Initial version presented Wednesday 1355 (GJS & JRO.)

This will include some testing with ALF disabled. The primary focus of the test will be relative to the VTM.

Add more detailed description of what parameters are to be provided for complexity analysis.

Use 10s sequences

[JVET-K1032](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4097) Description of Core Experiment 12 (CE12): Mapping functions [E. François, D. Rusanovskyy, P. Yin]

(Initial version presented Wednesday 1410 (GJS & JRO.)

[JVET-K1033](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4110) Description of Core Experiment 13 (CE13): Coding tools for 360° omnidirectional video [P. Hanhart, J.-L. Lin, C. Pujara]

Discussion Monday 2010 (GJS & JRO)

* Intra prediction, inter prediction, in-loop filters, padding, post-filtering, blending

(Initial version presented Wednesday 1415 (GJS & JRO.)

For pre- and post-processing, different amount of padding, blending, and post-filtering of seam artefacts will be tested. The tested solutions will be implemented for the hybrid equi-angular cubemap (HEC) projection and compared to the HEC with padding of 4 samples around face row with blending (PHEC) anchor.

Decision (CTC): The CTC will be changed to set the face size for cube projection to 1280x1280 and the ERP will be changed to 4432x2216.

[JVET-K1034](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4100) Description of Core Experiment 14 (CE14): Post-reconstruction filtering [L. Zhang, S. Ikonin]

Discussion Monday (GJS & JRO)

* Bilateral
* Hadamard-based

(Initial version presented Wednesday 1430 (GJS & JRO.)

[JVET-K1035](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4109) Description of Core Experiment 15 (CE15): Palette mode [Y.-C. Sun, Y. H. Chao, X. Xu]

Discussion Tuesday morning Track B (JRO)

* Investigate the palette variant proposed in JVET-K0411 and HEVC-SCC palette mode
* Investigate interrelationship with CPR
* Study the complexity impact of the two palette variants and CPR (in coordination with CE8)

(Initial version presented Wednesday 1430 (GJS & JRO.)

# 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 WG11 auspices in Marrakesh, 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 WG11 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 is Monday 31 Dec. 2018. Plans for scheduling of agenda items within that meeting remain TBA.

XXXX were thanked for the excellent hosting and organization of the 12th meeting of the JVET.

XXXX were thanked for providing viewing equipment used during the 12th JVET meeting.

XXXX was thanked for providing new test material for usage in standardization efforts.

The 12th JVET meeting was closed at approximately XXXX 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 XXX people in total), were as follows: