|  |  |
| --- | --- |
| **Joint Video Experts Team (JVET)**  **of ITU-T SG 16 WP 3 and ISO/IEC JTC 1/SC 29/WG 11**  13th Meeting: Marrakech, MA, 9–18 Jan. 2019 | Document: JVET-M\_Notes\_dB |

|  |  |  |  |
| --- | --- | --- | --- |
| *Title:* | **Meeting Report of the 13th meeting of the Joint Video Experts Team (JVET), Marrakech, MA, 9–18 January 2019** | | |
| *Status:* | Report document from the chairs of JVET | | |
| *Purpose:* | Report | | |
| *Author(s) or Contact(s):* | **Gary Sullivan** Microsoft Corp. 1 Microsoft Way Redmond, WA 98052 USA  **Jens-Rainer Ohm** Institute of Communication Engineering RWTH Aachen Melatener Straße 23 D-52074 Aachen | Tel: Email:  Tel: Email: | +1 425 703 5308 [garysull@microsoft.com](mailto:garysull@microsoft.com)  +49 241 80 27671 [ohm@ient.rwth-aachen.de](mailto:ohm@ient.rwth-aachen.de) |
| *Source:* | Chairs of JVET | | |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Summary

The Joint Video Experts Team (JVET) of ITU-T WP3/16 and ISO/IEC JTC 1/ SC 29/ WG 11 held its thirteenth meeting during 9–18 January 2019 at the Palais des Congrès Mogador (Tourist Zone Agdal, 40000, Marrakech, Morocco, Tel: + 212 530 530 530). 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 0910 hours on Wednesday 9 January 2019. Meeting sessions were held on all days (including weekend days) until the meeting was closed at approximately 1318 hours on Friday 18 October 2019. Approximately 283 people attended the JVET meeting, and approximately XXX input documents and 17 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 twelfth JVET meeting in producing a third draft of the VVC standard and the third version of the associated VVC test model (VTM). Further important goals were reviewing the results of 13 Core Experiments (CE), reviewing other technical input on novel aspects of video coding technology, and producing the next versions of the VVC draft text and VTM, and plan next steps for further investigation of candidate technology towards the formal standard development.

The JVET produced 18 output documents from the meeting:

* JVET-M1001 Versatile Video Coding specification text (Draft 4)
* JVET-M1002 Algorithm description for Versatile Video Coding and Test Model 4 (VTM 4)
* JVET-M1004 Algorithm descriptions of projection format conversion and video quality metrics in 360Lib (Version 9)
* JVET-M1006 Methodology and reporting template for coding tool testing and for neural network tool testing
* JVET-M1010, JVET-L1011, and JVET-L1012 JVET common test conditions and software reference configurations for SDR, HDR/WCG, and 360° video
* JVET-M1021 through JVET-M1033, Description of Core Experiments 1 through 13

For the organization and planning of its future work, the JVET established 19 “ad hoc groups” (AHGs) to progress the work on particular subject areas. At this meeting, 13 Core Experiments (CE) were defined. The next four JVET meetings were planned for 19–27 March 2019 under ITU-T SG16 auspices in Geneva, CH, during 3–12 July 2019 under WG 11 auspices in Gothenburg, SE, during 1–9 October 2019 under ITU-T SG16 auspices in Geneva, CH, and during 8–17 January 2020 under WG 11 auspices in Brussels, BE.

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 thirteenth meeting during 9–18 January 2019 at the Palais des Congrès Mogador (Tourist Zone Agdal, 40000, Marrakech, Morocco, Tel: + 212 530 530 530). 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/2019_01_M_Marrakech/>.

## Primary goals

As a primary goal, the JVET meeting reviewed the work that was performed in the interim period since the twelfth JVET meeting in producing a third draft of the VVC standard and the third version of the associated VVC test model (VTM). Further important goals were reviewing the results of 13 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 Wednesday, 2 January 2019. Any documents uploaded after 1159 hours Paris/Geneva time on Thursday 3 January 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-M0535 and higher were registered after the “officially late” deadline (and therefore were also uploaded late). However, some documents in the “M0535+” 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-M0XXX (a proposal on …), uploaded 01-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-M0XXX (a document on …), uploaded 01-XX.
* ….

The following cross-verification reports were registered before the deadline and uploaded late: JVET-M0XXX [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-M0XXX, ….

“Placeholder” contribution documents that were basically empty of content, or lacking any results proving benefit of the proposed technology, and obviously uploaded with an intent to provide a more complete submission as a revision, had been agreed to be considered unacceptable and to be rejected in the document management system until a more complete version was available (which would then typically be counted as a late contribution). At the current meeting, this situation applied to the initial uploads of documents JVET-M0245, JVET-M0325 (later withdrawn), JVET-M0351, JVET-M0396, JVET-M0424, JVET-M0526, and JVET-M0660.

Contributions that had significant problems with uploaded versions included the following:

* M0042 (improperly formatted filename)
* M0067 (proposal described as a report in header)
* M0080 (incorrect document number in a filename)
* M0084 (incomplete patent rights declaration)
* M0147 (no author or contact information in header)
* M0202 (incomplete patent rights declaration)
* M0204 (unreadable file uploaded)
* M0209 (unreadable file uploaded)
* M0244 (incorrect company identified in patent rights declaration)
* M0245 (proposal missing all clearly necessary experiment results)
* M0276 (incomplete patent rights declaration)
* M0325 (proposal missing all clearly necessary experiment results) – Later withdrawn
* M0336 (unreadable file uploaded in -v2)
* M0339 (unreadable file uploaded in -v2)
* M0351 (proposal missing all clearly necessary experiment results)
* M0352 (document number missing in header and most test results missing)
* M0374 (wrong meeting number in header)
* M0376 (wrong meeting start date in header)
* M0396 (proposal missing all clearly necessary experiment results)
* M0400 (wrong meeting start date and incorrect country abbreviation in header)
* M0416 (wrong meeting identified in header)
* M0424 (proposal missing all clearly necessary experiment results)
* M0481 (unreadable file uploaded)
* M0526 (proposal missing all clearly necessary experiment results)
* M0588 (copy of wrong contribution uploaded)
* M0594 (zero-byte zip file uploaded in -v2, another unreadable file uploaded later)
* M0605 (wrong document number in header)
* M0621 (uploaded file with confusing change marks relative to an irrelevant document)
* M0692 (uploaded file with confusing change marks relative to an irrelevant document)
* M0657 (title referred to the wrong document)
* M0660 (cross-check document with only a tiny fraction of the necessary experiment results)
* M0802, M0803, M0804, M0805, M0806, M0819, M0839 (document number missing in header)

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-L1000, the Versatile Video Coding specification text (Draft 3) JVET-L1001, the Algorithm description for Versatile Video Coding and Test Model 3 (VTM 3) JVET-L1002, the Algorithm descriptions of projection format conversion and video quality metrics in 360Lib Version 8 JVET-L1004, the Methodology and reporting template for tool testing JVET-L1005, the JVET common test conditions and software reference configurations for SDR, HDR/WCG, and 360° video (JVET-L1010, JVET-L1011, and JVET-L1012), and the Description of Core Experiments 1 through 13 (JVET-L1021 through JVET-L1033), had been completed and were approved. The software implementation of VTM (versions 3.0 and 3.1), and the 360Lib software implementation (version 8.0) were also approved.

The group had initially been asked to review the meeting report of the previous meeting for finalization. The meeting report was later approved … .

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 additional 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 [N 10791](http://phenix.it-sudparis.eu/mpeg/doc_end_user/current_document.php?id=27881&id_meeting=16) 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**: Adaptation parameter set.
* **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).
* **BDOF**: Bi-directional optical flow (formerly known as **BIO**).
* **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.
* **CE**: Core Experiment – a coordinated experiment conducted toward assessment of coding technology.
* **CG**: Coefficient group.
* **CGS**: Colour gamut scalability (historically, coarse-grained scalability).
* **CIIP**: Combined Inter/Intra prediction.
* **CL-RAS**: Cross-layer random-access skip.
* **CPMV**: Control-point motion vector.
* **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).
* **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).
* **HMVP**: History based motion vector prediction.
* **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.
* **SBT**: Subblock transform.
* **SbTMVP**: Subblock based temporal motion vector prediction.
* **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.
* **SMVD**: Symmetric MVD.
* **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.
* **TPM**: Triangular partitioning mode
* **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 9 January (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.
  + On placeholders – there were a number of cases where there was some description of a concept but no test results.
    - …
* The primary goals of the meeting were to review the results of CEs, identify promising technology directions, and adopt proposed technology into the VVC draft text and VTM.
* Due to the high number of input contributions, parallelization and breakout work were expected to be needed.
* Principles of standards development were discussed.

## Scheduling of discussions

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

* Wed. 9 January, 1st day
  + 0900–1100, 1130-1400 Opening plenary (chaired by GJS & JRO)
  + 1530–1700 Track A CE1: Partitioning [GJS]
  + 1750–2030 Track A CE3.1: Intra prediction and mode coding [GJS]
  + 1530–2100 Track B CE2: Subblock motion compensation [JRO]
* Thu. 10 January, 2nd day
  + 0900–1330, 1500–1630 Track A CE3.2 & CE3.3 Intra prediction & mode coding [GJS]
  + 1700–2030 Track A CE5: Arithmetic coding engine [Y. Ye]
  + 2030–2200 Track A CE6: Transforms and transform signalling [GJS]
  + 0900–1100 Track B CE2: Subblock motion compensation [JRO]
  + 1120–1340, 1500-2000 Track B CE4: Inter prediction and motion vector coding [JRO]
  + 2030–2230 Track B CE9: Decoder-side motion vector derivation [JRO]
  + 0900–2100 BoG on tiles & wavefronts [Y.-K. Wang & M. M. Hannuksela in Chellah [JVET-M0782](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5613)]
  + 2030–2300 BoG on CE2 related [Y. He in Lixus [JVET-M0862](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5693)]
* Fri. 11 January, 3rd day
  + 0900–1100, 1130–1400, 1530–2000 Track A CE6: Transforms and transform signalling [GJS]
  + 0900–1100 Track B CE11: Deblocking [JRO]
  + 1120–1330 and 1500–1615 Track B CE8: Screen content coding tools [JRO]
  + 1620–2010 Track B CE8 related screen content coding [JRO]
  + 0900–2100 BoG on high-level syntax [J. Boyce in Chellah [JVET-M0816](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5647)]
  + 0900–1300, 1500–1900 BoG on CE3 and CE3-related intra prediction and mode coding [G. Van der Auwera in Ourica [JVET-M0857](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5688)]
  + 1540–2020 BoG on CE4 related inter prediction and motion vector coding [K. Zhang [JVET-M0843](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5674)]
  + 2045–2330 BoG on CE2 subblock motion compensation [Y. He in Lixus [JVET-M0862](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5693)]
* Sat. 12 January, 4th day
  + 0900–1330 JCT-VC [outside of JVET in Chella]
  + 0900–1045, 1830–2300 BoGs sharing room in Olympia, then Colliseum
    - BoG on CE4 related inter prediction and motion vector coding [K. Zhang [JVET-M0843](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5674)]
    - BoG on CE2 subblock motion compensation [Y. He [JVET-M0862](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5693)]
  + 0900–1300, 1500–1800 BoG on CE3 and CE3-related intra prediction and mode coding [G. Van der Auwera in Colliseum in morning, Salon marocain in afternoon [JVET-M0857](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5688)]
  + 1130–1345, 1515–1815 Track B on CE10: Combined and multi-hypothesis prediction [JRO]
  + 1300– BoG on CE9 related decoder-side motion vector derivation [S. Esenlik [JVET-M0858](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5689)]
  + 1500–1600 Track A CE7: Quantization and coefficient coding [GJS]
  + 1600–1645, 1700–1800 Track A CE12 – Mapping functions [GJS]
  + 1600–1740 BoG on tiles & wavefronts [Y.-K. Wang & M. M. Hannuksela in Chellah [JVET-M0782](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5613)]
  + 1800–1830 Track A CE12 related – Mapping functions [GJS]
  + 1815–2130 Track B CE8 related screen content coding [JRO]
  + 1800–2100 BoG on high-level syntax [J. Boyce in Chellah [JVET-M0816](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5647)]
* Sun. 13 January, 5th day
  + 0900–1045, 1115–1400 Plenary
  + 1530–1645, 1700–1800 Track A BoG reporting on high-level syntax [JVET-M0816](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5647)
  + 1530–1800 Track B Loop filtering [JRO]
  + 1530-XXXX BoG on CE13 and CE13 related 360° video coding [J. Boyce in Chella [JVET-M0874](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5705)]
  + 1530-XXXX BoG on CE6 related transforms and transform signalling [X. Zhao in Luxor [JVET-M0877](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5708)]
  + 1530-XXXX BoGs sharing room in Salon marocain
    - BoG on CE4 related inter prediction and motion vector coding [K. Zhang [JVET-M0843](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5674)]
    - BoG on CE2 subblock motion compensation [Y. He [JVET-M0862](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5693)]
  + 1800 BoG on CE10 related [C.-W. Hsu and M. Winken in Olympia [JVET-M0873](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5704)]
* Mon. 14 January, 6th day
  + 0900–1400 MPEG parent-body opening plenary
  + 1300–XXXX Track A BoG reporting
    - 1300-1430 BoG on HLS
    - 1430-1630, 1920-2000 BoG on tiles and wavefronts [JVET-M0782](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5613)
  + 2015–2240 Track A Use case studies and general prediction [GJS]
  + 1400?, 1930– BoG on CE10 related [C.-W. Hsu and M. Winken in Olympia, then Ourika [JVET-M0873](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5704)]
  + 1600–1945 Track B [JRO]
    - 1600-1715 6.14 Loop filtering tools
    - 1715–1815 6.11 CE11 related (deblocking)
    - 1815–1945 6.18 Tools based on NN technology
  + 1700–1830 VCEG parent-body opening plenary [outside of JVET in Chellah]
  + 1900 BoG on CE7 related quantization and coefficient coding [Y. Ye in Sabah [JVET-M0891](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5722)]
  + 1845–XXXX BoG on CE13 and CE13 related 360° video coding [J. Boyce in Lodge 2, then Chella [JVET-M0874](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5705)]
  + 1900–XXXX BoGs sharing room in Olympia
    - BoG on CE4 related inter prediction and motion vector coding [K. Zhang [JVET-M0843](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5674)]
    - BoG on CE2 subblock motion compensation [Y. He [JVET-M0862](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5693)]
  + 2230–XXXX BoG on CE6 related transforms and transform signalling [X. Zhao in Luxor [JVET-M0877](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5708)]
* Tue. 15 January, 7th day
  + 0900–1000 VCEG-MPEG joint meeting [incl. JVET systems coord, in Lixus]
  + 1030–1400 JCT-VC meeting [outside of JVET in Chella]
  + 1000–1215 Track B BoG on CE2 reporting in Olympia [JRO]
  + 1215–1330, 1430–1800 Track B BoG on CE4 reporting in Coliseum [JRO]
  + 1430–1630 Track A BoG reporting on CE3 related intra prediction and mode coding [JVET-M0857](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5688)
  + 1700 Track A BoG reporting on CE6 related transforms and transform signalling [X. Zhao [JVET-M0877](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5708)]
  + 1800 BoG on high-level syntax (J. Boyce in Chellah [JVET-M0816](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5647))
  + 1915 BoG on complexity analysis and reduction [A. Filippov & B. Bross in Coliseum.
  + 2000 BoG on quantization control (8) [Y. Ye in Olympia]
  + XXXX BoG on tools based on NN technology (7) (section 6.18) (Y. Li)
* Wed. 16 January, 8th day
  + 0900–1115 MPEG mid-week plenary
  + 1115–1330 Track B BoG on CE9 reporting in Olympia [JRO]
  + 1130–1200 VCEG-MPEG joint meeting (outside of JVET in Lixus)
  + 1200–1300 MPEG liaison meeting (outside of JVET)
  + 1300 BoG on CE7 related quantization and coefficient coding (13) [Y. Ye in Saba [JVET-M0891](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5722)]
  + 1300–1400 Track A BoG reporting on CE6 related transforms and transform signalling [X. Zhao [JVET-M0877](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5708)]
  + 1400–1445 Track A BoG reporting on high-level syntax [JVET-M0816](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5647)
  + 1445–1515 Track A BoG further review on tiles and wavefronts [JVET-M0782](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5613)
  + 1500–1820 Track B BoG on CE10 reporting in Olympia [JRO]
  + 1515–1630 Track A BoG reporting on complexity analysis and reduction M0902 and related contribution M0265.
  + 1645–1800 Track A BoG reporting on quantization control M0901
  + 1700–XXXX BoG on CE13 and CE13 related 360° video coding [J. Boyce in Chella [JVET-M0874](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5705)]
  + 1820 Departures starting for social event @ Soleiman Palace
* Thu. 17 January, 9th day
  + 0900–0930 JVET-VCEG-MPEG joint meeting on systems interface in Coliseum
  + 1400–1500 ISO standards editing guidance [Outside of JVET in Lixus]
  + 0930–1200 JVET plenary
  + 1200–1330 Track B: Review of CE11 viewing results [JRO]
  + 1500–1815 Track B Review of NN BoG, revisits [JRO]
  + 1200 JCT-VC (outside of JVET)
  + 1300 BoG on CE7 related quantization and coefficient coding (13) [Y. Ye in Saba [JVET-M0891](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5722)]
  + 1500–1545 Track A further discussion of VPDU shape penalty and special treatment of edges in CE1
  + 1545–1600 Track A further discussion of CE6-5 secondary transform
  + 1600–1700 Track A BoG reporting on 360° video (CE13 & related [JVET-M0874](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5705))
  + 1700–1800 Track A BoG reporting on CE7 related quantization and coefficient coding [Y. Ye [JVET-M0891](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5722)]
  + XXXX Track A Use case studies and general prediction (3 remaining)
  + XXXX Track A CE5-related entropy coding (1 needing presentation)
  + XXXX Track A Entropy coding (1)
  + XXXX Track A CE1 related partitioning (1 TBP)
  + XXXX Track A Encoder optimization (3)
  + XXXX Plenary common test conditions (1)
  + XXXX Plenary software development (1)
  + 1800 MPEG chairs meeting
* Fri. 19 January, 10th day
  + 0800–0900 Track B on CE11 and CE11 related revisits [JRO]
  + 0800 VCEG? (outside of JVET)

## Contribution topic overview

The approximate subject categories and quantity of contributions per category for the meeting were summarized as follows (note that document count does not include crosschecks, and may not be up to date):

* AHG reports (17) (section 3) (Plenary)
* Project development (10) (section 4) (Plenary)
  + Software development (1)
  + Common test conditions (1)
  + Coding studies and specific use cases (8)
* Core Experiments (xx) (section 5) with subtopics
  + CE1: Partitioning (3) (section 5.1) (Track A)
  + CE2: Subblock motion compensation (24) (section 5.2) (Track B)
  + CE3: Intra prediction and mode coding (16) (section 5.3) (Track A)
  + CE4: Inter prediction and motion vector coding (18) (section 5.4) (Track B)
  + CE5: Arithmetic coding engine (10) (section 5.5) (Track A)
  + CE6: Transforms and transform signalling (21) (section 5.6) (Track A)
  + CE7: Quantization and coefficient coding (2) (section 5.7) (Track A & BoG [JVET-M0891](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5722))
  + CE8: Screen content coding tools (15) (section 5.8) (Track B)
  + CE9: Decoder side motion vector derivation (8) (section 5.9) (Track B)
  + CE10: Combined and multi-hypothesis prediction (15) (section 5.10) (Track B)
  + CE11: Deblocking (9) (section 5.11) (Track B)
  + CE12: Mapping functions (2) (section 5.12) (Track A)
  + CE13: Coding tools for 360° video (11) (section 5.13) (Track A & BoG [JVET-M0874](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5705))
* Non-CE technology proposals (xx) (section 6) with subtopics
  + CE1 related – Partitioning (3) (section 6.1) (Track A)
  + CE2 related – Subblock motion compensation (31) (section 6.2) (Track B & BoG Y. He [JVET-M0862](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5693))
  + CE3 related – Intra prediction and mode coding (50) (section 6.3) (Track A & BoG G. Van der Auwera [JVET-M0857](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5688))
  + CE4 related – Inter prediction and motion vector coding (49) (section 6.4) (Track B & BoG K. Zhang [JVET-M0843](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5674))
  + CE5 related – Arithmetic coding engine (4) (section 6.5) (Track A)
  + CE6 related – Transforms and transform signalling (25) (section 6.6) (Track A & BoG X. Zhao [JVET-M0877](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5708))
  + CE7 related – Quantization and coefficient coding (13) (section 6.7) (Track A & BoG Y. Ye)
  + CE8 related – Screen content coding tools (29) (section 6.8) (Track B)
  + CE9 related – Decoder side motion vector derivation (12) (section 6.9) (Track B & BoG S. Esenlik [JVET-M0858](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5689))
  + CE10 related – Combined and multi-hypothesis prediction (42) (section 6.10) (Track B & BoG C.-W. Hsu & M. Winken [JVET-M0873](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5704))
  + CE11 related – Deblocking (3) (section 6.11) (Track B)
  + CE12 related – Mapping functions (2) (section 6.12) (Track A)
  + CE13 related – Coding tools for 360° content (7) (section 6.13) (Track A & BoG J. Boyce [JVET-M0874](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5705))
  + Loop filtering tools (12) (section 6.14) (Track B)
  + General prediction aspects (5) (section 6.15) (Track A)
  + Quantization control (8) (section 6.16) (Track A & BoG Y. Ye)
  + Entropy coding (2) (section 6.17) (Track A)
  + Tools based on NN technology (7) (section 6.18) (Track B & BoG Y. Li)
  + High-level syntax (51) (section 6.19) (Track A & BoG Y.-K. Wang & M. M. Hannuksela on tiles & wavefronts [JVET-M0782](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5613) & BoG J. Boyce [JVET-M0816](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5647))
* Complexity analysis and reduction (10) (section 7) (Track A & BoG A. Filippov & B. Bross)
* Encoder optimization (3) (section 8) (Track A)
* Metrics and evaluation criteria (0) (section 9) (Track none)
* Withdrawn (13) (section 10) (Track none)
* 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 (238) was generally chaired by GJS, and Track B (272) by JRO.

As a general remark, it was established in Track B that “further study” means that technology should be studied in next CE on the subject area, whereas if such a remark is missing it implicitly means it should not be studied in CE. If further study in an AHG is expected, that would be explicitly expressed.

# AHG reports (17)

These reports were discussed Wednesday 9 January XXXX-XXXX (chaired by GJS and JRO).

[JVET-M0001](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4898) JVET AHG report: Project management (AHG1) [J.-R. Ohm, G. J. Sullivan]

This document reported 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.

At the 12th meeting of the ITU-T/ISO/IEC Joint Video Experts Team (JVET), an *ad hoc* group on Project Management was established with the following mandates:

* 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.

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

In the interim period since the 12th JVET meeting, work towards finalizing the following (21) documents had been performed:

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

The work of the JVET overall had proceeded well in the interim period, and many input documents had been submitted for consideration at the current meeting. Intense discussion had been carried out on the group email reflector, and all output documents from the preceding meeting had been produced.

As noted below, all 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_10_M_Macao/>), although some of these documents were noted to potentially need further refinement:

* The meeting report (JVET-L1000) [Posted 2019-01-08]
* Versatile Video Coding (Draft 3) (JVET-L1001) [Posted 2018-10-31, last update 2019-01-08]
* Algorithm description for Versatile Video Coding and Test Model 3 (VTM 3) (JVET-L1002) [Posted 2018-12-03, last update 2018-12-24]
* Algorithm descriptions of projection format conversion and video quality metrics in 360Lib Version 8 (JVET-L1004) [Posted 2018-11-10]
* Methodology and reporting template for coding tool testing (JVET-L1005) [Posted 2018-10-27]
* Methodology and reporting template for neural network coding tool testing (JVET-L1006) [Posted 2018-10-25]
* JVET common test conditions and software reference configurations (JVET-L1010) [Posted 2018-11-16]
* JVET common test conditions and evaluation procedures for HDR/WCG video (JVET-L1011) [Posted 2018-11-20]
* JVET common test conditions and evaluation procedures for 360° video (JVET-L1012) [Posted 2018-11-19]

Description of CE 1..13 (JVET-L1021..35) [all first posted 2018-10-11 or 2018-10-12, further updated during the CE definition period of 3 weeks after the meeting, i.e., until 2018-11-02]. The following CE description documents had substantially later updates (more than 4 weeks after the meeting):

* JVET-L1022 [last updated 2019-01-08] (for which some experiment plans had changed and the change had been announced on the JVET reflector)
* JVET-L1023 [last updated 2018-12-27]
* JVET-L1024 [last updated 2019-01-08] (for which some experiment plans had changed but the change had not been announced on the JVET reflector)
* JVET-L1025 [last updated 2019-01-04]
* JVET-L1026 [last updated 2019-01-04]
* JVET-L1027 [last updated 2018-11-13]
* JVET-L1033 [last updated 2018-11-27]

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

Software integration of the VTM 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 had been migrated to GitLab before the previous meeting, and the method for obtaining access to the software had been changed after the last meeting – using shared accounts for read access by members (with one account for MPEG members using its usual credentials and another for VCEG members with access managed through the TIES system). The bug tracking system for software aspects was not integrated yet with GitLab for the time being.

At the time the meeting began, roughly 700 input contributions to the current meeting (not counting the AHG reports) had been registered for consideration at the meeting. Though the topics of Core Experiments and related documents for the development of low-level coding tools reflected the bulk of these documents, around 50 documents were submitted on aspects of high-level syntax, including tile partitioning.

A preliminary basis for the document subject allocation and meeting notes for the 13th meeting had been made publicly available on the ITU-hosted site.

[JVET-M0002](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4943) 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 12th meeting in Macao, CN (3–12 October 2018) and the 13th meeting in Marrakech, MA (9–18 January 2019).

At the 12th 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 tile group based high-level syntax in the third draft of Versatile Video Coding (VVC D3) and the VVC Test Model 3 (VTM3) encoding. Draft reference software to implement the VVC decoding process and VTM3 encoding method had also been developed.

The normative decoding process for Versatile Video Coding is specified in the VVC draft 3 text specification document. The VVC Test Model 3 (VTM 3) Algorithm and Encoder Description document provides an algorithm description as well as an encoder-side description of the VVC Test Model 3, which serves as a tutorial for the algorithm and encoding model implemented in the VTM3.0 software.

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

Nine versions of the JVET-L1001 VVC draft 3 specification text were published by the editing AHG between the 12th meeting in Macao, CN (3–12 October 2018) and the 13th meeting in Marrakech, MA (9–18 January 2019).

The specific items integrated into the text were listed in the AHG report.

The following items had been discussed within the AHG:

* Deblocking over SubCUs: There had been two different understandings of the decision from the last meeting how deblocking over SubPU boundaries is performed – recorded as "Recommendation: Apply the same logic to VVC (both ATMVP and affine) sub-blocks (on 8x8 grid) as to PU in HEVC deblocking. This means check the deblocking motion conditions for ATMVP and affine motion sub-block boundaries as if they were PUs in HEVC". The two interpretations were:
* All edges on a 8x8 sample grid can be deblocked, irrespective of the type of the edge (i.e. CU, SubCU, TU edge).
* Only Sub-CU and TU edges of a CU that is aligned on the 8x8 grid in one direction can be deblocked in the respective direction.

The current draft and the VTM-3.0 macro L0074\_SUBBLOCK\_DEBLOCKING followed the second understanding. However, the AHG requested JVET to discuss which solution is preferred. The following document was identified to be related:

* JVET-M0339 CE11-related: subblock boundary filter at 8x8 Grid [H. Jang, J. Nam, S. Kim, J. Lim (LGE)]
* Interaction of CPR with other newly adopted inter tools: There had been six items discussed which were related to CPR interaction with newly adopted inter tools. They were summarized as follows.

1. In the current draft spec, when the first merge candidate of the current CU is coded in CPR mode, (0, 0) motion vector is used for the derivation of the collocated block, while in VTM-3.0, the next merge candidate will be examined. It was recommended to change the software to match the spec. A related contribution JVET-M0409 was noted.
2. For CPR to work with the newly adopted pairwise average merging candidates, two options were discussed:
   * Option 1. Disallow any combination involves CPR
   * Option 2. Integrate CPR-CPR combination in draft text.

The draft spec and VTM-3.0 had implemented Option 2.

1. For CPR interaction with Affine motion, neither current draft spec nor VTM-3.0 allows the combination of both being enabled at the same time. Bitstream conformance check is used in both VTM-3.0 and the current draft spec. The generation of merge candidate excludes CPR neighbours, while the generation of motion vector predictor (AMVP mode) includes CPR neighbors.
2. For CPR interaction with MMVD partition, neither current draft spec nor VTM-3.0 allows the combination of both being enabled at the same time. Bitstream conformance check is used in both VTM-3.0 and the current draft spec. The generation of MMVD base motion vector excludes CPR neighbors.
3. For CPR interaction with Triangular partition, neither current draft spec nor VTM-3.0 allows the combination of both being enabled at the same time. Bitstream conformance check is used in both VTM-3.0 and the current draft spec. The generation of partition motion vector excludes CPR neighbors.
4. For CPR interaction with CIIP, neither current draft spec nor VTM-3.0 allows the combination of both being enabled at the same time. Bitstream conformance check is used in both VTM-3.0 and the current draft spec. The generation of inter-merge motion vector includes CPR neighbors.

* The maximum number of HMVP candidates is 6 but six cases were never actually used and thus can be reduced to 5. The following document was identified to be related:
* JVET-M0436 AHG2: Regarding HMVP Table Size [J. Zhao, S. Kim (LGE)]
* Open bug tracker issues (tickets): The following tickets were suggested to need discussion:
  + [#128](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/128) incorrect modulo value used in adjacent mode calculations. Is there a mismatch between VTM and spec?
  + [#132](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/132) Mismatch between specification and software in the order of syntax elements for intra prediction
  + [#135](https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/135) DCT2 transform matrix down-sampling might be wrong in the spec

In the JVET discussion of these items, the following outcomes were agreed:

* + No action was needed on ticket #128.
  + Decision (SW): A software fix was needed for #132. [Check inclusion in decision list]
  + Decision: The downsampling of the DCT2 transform matrix should be separate horizontally and vertically (not assumed square) for #135.

Two versions of the JVET-L1002 VVC Test Model 3 (VTM 3) document were published by the Editing AHG between the 12th meeting in Macao, CN (3–12 October 2018) and the 13th meeting in Marrakech, MA (9–18 January 2019). The items added to VTM 3 were listed in the AHG report.

A general encoder description and some other features such as high-level syntax, the tiling mechanism and miscellaneous small coding features (such PCM mode and Delta QP signalling) had yet to be added to the document.

The AHG recommended to:

* Approve the edited JVET-L1001 and JVET-L1002 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 are made available in a timely manner.

[JVET-M0003](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4944) JVET AHG report: Test model software development (AHG3) [F. Bossen, X. Li, K. Sühring]

[Add content from report]

Ticket #105 on mode combinations allowed.

v3.1 to be released during meeting.

To add software account access information in a revision.

Remarks on CTC:

* CPR is not enabled (perhaps should enable for SCC test sequences)
* MTS is not enabled for inter (perhaps should enable for low-res test sequences)

[JVET-M0004](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4876) JVET AHG report: Test material and visual assessment (AHG4) [T. Suzuki, V. Baroncini, R. Chernyak, P. Hanhart, A. Norkin, J. Ye]

The test sequences used for CfP/CTC 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).

There was discussion that the current directory structure of test sequence ftp site is not good for the current activities. The ftp directory was created during the preparation of CfE/CfP and the same directory structure is still used. One possibility is to re-design the directory as follows, for example,

* ctc/ : Contains the active test set of the common testing conditions
* ahg/ : Contains subdirectories with sequences under consideration. The subfolder might be structured by meeting period (e.g. named by the doc-number of the corresponding meeting report?)
* ce/ : Contains subdirectories for data exchange for specific CE (already implemented, see ce/JVET-{K,L}1031\_Deblocking
* upload : stays as before

During the last meeting, there was a comment that all sequences, all classes should be at the same place. But there is still meaningful to separate SDR, HDR, 360. Further detail should be discussed in the meeting.

The AHG recommended:

* To discuss further ftp directory structure
* To continue to collect new test sequences available for JVET with licensing statement

It was noted that some test sequences had been submitted to the previous meeting, and that there was especially some interest in improving the SCC test set. Side activity was encouraged to study that.

[JVET-M0005](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5220) JVET AHG report: Memory bandwidth consumption of coding tools (AHG5) [R. Hashimoto, T. Ikai, X. Li, D. Luo, H. Yang, M. Zhou]

The document summarizes activities of AHG on memory bandwidth consumption of coding tools between the 12th and the 13th JVET meetings.

There is no related email discussion during this meeting cycle.

A patch on memory bandwidth measurement tools on VTM-3.0 has been provided by the AHG

<https://jvet.hhi.fraunhofer.de/trac/vvc/ticket/121>

Contributions to this meeting are as follows.

* CE2.4 (affine motion / block restriction) and related contributions
  + JVET-M0049 “CE2-related: A restriction on memory bandwidth consumption of affine mode”, M. Zhou (Broadcom)
  + JVET-M0150 “CE2.4.3: Affine restriction for worst-case memory bandwidth reduction”, L. Pham Van, W.-J. Chien, H. Huang, V. Seregin, M. Karczewicz (Qualcomm)
  + JVET-M0226 “CE2: Reducing worst-case memory bandwidth of affine mode (test 2.4.1)”, Y.-W. Chen, X. Wang (Kwai Inc.)
  + JVET-M0309 “CE2: Memory bandwidth reduction for affine mode (test 2.4.2)”, J. Li, R.-L. Liao, C. S. Lim (Panasonic)
  + JVET-M0311 “CE2-related: Memory bandwidth reduction for affine mode with less dependency”, J. Li, R.-L. Liao, C. S. Lim (Panasonic)
  + JVET-M0400, “CE2-related: Worst-case memory bandwidth reduction for VVC”, W.-J. Chien, L. Pham Van, H. Huang, V. Seregin, M. Karczewicz (Qualcomm)
  + JVET-M0472 “CE2: Affine sub-block size restrictions (Test 2.4.4)”, H. Chen, T. Solovyev, H. Yang, J. Chen (Huawei)
  + JVET-M0488 “CE2: Sub-block MV clip in affine prediction (test 2.4.5)”, M Gao, X Li, M Xu, S Liu(Tencent)
  + JVET-M0702 “CE2-related: Adaptive sub-block MV clip for affine blocks”, X. Li, M. Gao, S. Liu (Tencent)
* CE4.5 (block size restriction) and related contributions
  + JVET-M0313 “CE4: Motion compensation constraints for complexity reduction (test 4.5.1 and test 4.5.2)”, R.-L. Liao, J. Li, C. S. Lim (Panasonic)
  + JVET-M0348 “CE4-related: Further reducing VVC memory bandwidth worst case by combining 4x4/4x8/8x4 bi-prediction with AMVR”, X.W. Meng (Peking University), X. Zheng (DJI), S.S. Wang, S.W. Ma
* Others
  + JVET-M0357 “CE10-related: Reduction of the worst-case memory bandwidth and operation number of OBMC”, Y. Kidani, K. Kawamura, K. Unno, S. Naito (KDDI)

The AHG recommended to review the related contributions.

[JVET-M0006](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5276) 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 12th (3 – 12 Oct. 2018) and the 13th (9 – 18 Jan. 2019) JVET meetings.

Brief summary for the activities:

The 360Lib-8.0 software package included following changes:

* Projection format conversion:
  + Chroma sample location type support (JVET-L0238).
* Configurations:
  + Added chroma sample location type for the output in the encoding parameter settings.

Software:

* Fixed the compilation error reported by ticket #118 to support GCC 8.2.1.

360Lib-8.0 related release:

* 360Lib-8.0rc1 with support of VTM-3.0rc1 was released on Nov. 16, 2018;
* 360Lib-8.0 with support of VTM-3.0 was released on Nov. 22, 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-8.0 can be found at:

https://jvet.hhi.fraunhofer.de/svn/svn\_360Lib/tags/360Lib-8.0/

360Lib-8.0 testing results can be found at:

ftp.ient.rwth-aachen.de/testresults/360Lib-8.0

360Lib bug tracker

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

The first table below is for the projection formats comparison using VTM-3.0 according to 360o video CTC (JVET-L1012). It compares padded hybrid equi-angular cubemap (PHEC) coding and padded equi-rectangular projection (PERP) coding using VTM-3.0.

**VTM-3.0 PHEC vs PERP (VTM-3.0 PERP as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **PHEC over PERP (VTM-3.0)** | | | | | |
|  | **End-to-end WS-PSNR** | | | **End-to-end S-PSNR-NN** | | |
|  | Y | U | V | Y | U | V |
| Class S1 | -11.14% | -8.48% | -8.95% | -11.06% | -8.40% | -8.90% |
| Class S2 | -4.99% | -5.50% | -5.75% | -4.97% | -5.40% | -5.67% |
| **Overall** | -8.68% | -7.29% | -7.67% | -8.62% | -7.20% | -7.61% |

The next table below is for PERP comparison between these two codecs.

**VTM-3.0 PERP vs HM-16.16 PERP (HM-16.16 PERP as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **VTM-3.0 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 | -21.25% | -40.15% | -40.88% | -21.24% | -40.15% | -40.82% |
| Class S2 | -29.62% | -44.01% | -44.94% | -29.61% | -44.03% | -44.97% |
| **Overall** | -24.60% | -41.69% | -42.50% | -24.59% | -41.70% | -42.48% |

The following table is to compare VTM-3.0 with PHEC coding and HM-16.16 with CMP coding.

**VTM-3.0 PHEC vs HM-16.16 CMP (HM-16.16 CMP as anchor)**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **VTM-3.0 PHEC - Over HM-16.16 CMP** | | | | | |
|  | **End-to-end WS-PSNR** | | | **End-to-end S-PSNR-NN** | | |
|  | Y | U | V | Y | U | V |
| Class S1 | -25.82% | -41.35% | -41.88% | -25.71% | -41.32% | -41.84% |
| Class S2 | -32.70% | -47.14% | -48.10% | -32.69% | -47.13% | -48.11% |
| **Overall** | -28.57% | -43.66% | -44.37% | -28.50% | -43.65% | -44.35% |

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

[JVET-M0007](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5553) JVET AHG report: Coding of HDR/WCG material (AHG7) [A. Segall, E. François, D. Rusanovskyy]

This document summarizes the activity of AHG7: Coding of HDR/WCG Material between the 12th meeting in Macao, CN (3–12 October 2018) and the 13th meeting in Marrakech, MA (9–18 January 2019).

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 arranging for a demonstration event for viewing JVET-L0205 and JVET-L0245 and maintaining test content. This work is described in the following subsection.

Demonstration Event

In the previous AHG study (as well as the previous JVET meeting), it was determined that it was unlikely that HDR viewing equipment would be present at the Marrakech meeting due to meeting logistics. In response to that, some HDR proponents proposed to have a demonstration event during the recent AHG period. The goal of the demonstration event was to facilitate the viewing of JVET-L-0205 and JVET-L0245.

During the AHG study period, several companies and locations were contacted to schedule such an event. However, all contacts reported scheduling issues due to year-end HDR movie title releases as well as industry preparation for the Consumer Electronics Show (CES). Because of these scheduling issues, no event was held.

It was observed that the situation continues to enforce the importance of HDR content in current, consumer entertainment and consumer electronic industries.

Maintaining Test Content

During the recent meetings, it has been determined that there are some inconsistencies in how the copyright statements are managed within the HDR test sequences. For example, some sequences contain the copyright statement as a text file, while other sequences include the copyright sequences in the last frame of the sequence. During the AHG period, there was an effort to clean up and unify the copyright handling, with emphasis on the HLG content. While this did not affect the content of any sequence, it did result in changing the md5sums for the sequences (in cases that had copyright frames). These changes were also reflected in the CTCs.

There were 6 contributions identified as related to HDR video coding:

* JVET-M0032 CE12: Summary report on mapping functions [E. Francois, P. Yin]
* JVET-M0109 CE12-related: block-based in-loop reshaping [E. Francois, C. Chevance, F. Hiron (Technicolor)]
* JVET-M0427 CE12: Mapping functions (test CE12-1 and CE12-2) [T. Lu, F. Pu, P. Yin, W. Husak, S. McCarthy, T. Chen (Dolby)]
* JVET-M0580 Crosscheck of JVET-M0109 (CE12-related: block-based in-loop luma reshaping) [T. Lu, P. Yin (Dolby)]
* JVET-M0640 CE12-related: in-loop reshaping with approximate inverse mapping function [E. Francois (Technicolor)]
* JVET-M0703 Crosscheck of JVET-M0640 (CE12-related: in-loop luma reshaping with approximate inverse mapping function) [T. Lu, P. Yin]

The AHG recommended to review the related input contributions and discuss whether a demonstration and/or viewing event should be performed prior to (or at the) 14th JVET meeting.

[JVET-M0008](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5543) 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 12th meeting in Macao, CN (3–12 October 2018) and the 13th meeting in Marrakech, MA (9–18 January 2019).

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

There were five non-CE related input documents identified (three contributions and one cross-check) related to 360º video coding, which are listed below. In addition, CE13 on projection formats is related to 360º video coding, and has ten input documents, which will be described in the CE report in JVET-M0033. There are four additional CE13-related input documents (three contributions and one cross-check) listed below.

360 video contributions not related to CE13

JVET-M0225

AHG8: On wrap around motion compensation [B. Choi, W. Feng, S. Liu (Tencent)

JVET-M0368

AHG8: 360Lib support for chroma sample location in PHEC blending process [C.-H. Shih, Y.-H. Lee, J.-L. Lin, Y.-C. Chang, C.-C. Ju (MediaTek)

JVET-M0452

AHG8: Hemisphere cubemap projection format [J. Boyce, M. Dmytrychenko (Intel)

Crosschecks of 360 video contributions not related to CE13

JVET-M0644

Crosscheck of JVET-M0368 (AHG8: 360Lib support for chroma sample location in PHEC blending process) [P. Hanhart (InterDigital)

CE13-related contributions

JVET-M0322

CE13-related: In-loop filters disabled across face discontinuities on PHEC with 2-pixel padding [Yule Sun, Xuchang Huangfu, Lu Yu (Zhejiang Univ.)

JVET-M0323

CE13-related: Adaptive QP to improve subjective quality for PHEC [Yule Sun, Xuchang Huangfu, Lu Yu (Zhejiang Univ.)

JVET-M0534

CE13-related: HEC with Pre-rotation + Adaptive Frame Packing(Test 4.2.a+4.1) [C. Pujara, A. Konda, A. Singh, R. Gadde, W. Choi, K. Choi, K.P. Choi(Samsung)

JVET-M0547

360° coding tools using uncoded areas [J. Sauer, M. Bläser

Crosschecks of 360 video contributions not related to CE13

JVET-M0645

Crosscheck of JVET-M0534 (CE13-related: HEC with Pre-rotation + Adaptive Frame Packing(Test 4.2.a+4.1)) [P. Hanhart (InterDigital)

Recommendations

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-M0009](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5526) JVET AHG report: Neural Networks in Video Coding (AHG9) [S. Liu, B. Choi, K. Kawamura, Y. Li, L. Wang, P. Wu, H. Yang]

[add notes]

[JVET-M0010](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5567) JVET AHG report: Encoding algorithm optimizations (AHG10) [A. M. Tourapis, A. Duenas, C. Helmrich, S. Ikonin, A. Norkin, R. Sjöberg]

[add abstract]

[JVET-M0011](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5423) JVET AHG report: Screen Content Coding (AHG11) [S. Liu, J. Boyce, A. Filippov, Y.-C. Sun, J. Xu, M. Zhou]

This document summarizes the activity of AHG11: Screen Content Coding between the 12th meeting in Macao, CN (3 – 12 Oct 2018) and the 13th meeting in Marrakech, MA (9–18 Jan. 2019).

The AHG used the main JVET reflector, jvet@lists.rwth-aachen.de, with [AHG11] in message headers. There were about a dozen emails exchanged on the JVET reflector with some discussions about testing sequences. There were also some email discussions about the interaction between CPR and inter coding tools adopted in Macao. Through the discussions, some mismatches between software VTM3 and spec VVC Draft 3 were identified. Some possible solutions are suggested in JVET-M0409. More in-depth technical discussions were carried in CE8 mailing list.

In total there are 26 CPR related technical contributions, 8 Palette related technical contributions and 7 other SCC related technical contributions identified for this meeting.

* CPR related:
  + JVET-M0151, CE8-related: Virtual search area for current picture referencing (CPR), L. Pham Van, T. Hsieh, W.-J. Chien, V. Seregin, H. Wang, M. Karczewicz (Qualcomm)
  + JVET-M0174, CE8-related: Removal of subblock-based chroma MC in CPR, C.-Y. Lai, T.-D. Chuang, Y.-L. Hsiao, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)
  + JVET-M0175, CE8-related: Clarification on interaction between CPR and other inter coding tools, C.-Y. Lai, T.-D. Chuang, Y.-L. Hsiao, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)
  + JVET-M0254, Non-CE8: Subblock Operation Removal for Chroma CPR, J. Xu, K. Zhang, L. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)
  + JVET-M0325, CE8-related: CPR with previous CTU availability at frame and tile edge, C. Rosewarne, A. Dorrell (Canon) – Later withdrawn
  + JVET-M0326, CE8-related: Remove the redundancy of CPR-related syntax coding, S. Ye, F. Chen, L. Wang (Hikvision)
  + JVET-M0327, CE8-related: A new CPR syntax scheme, S. Ye, F. Chen, L. Wang (Hikvision)
  + JVET-M0332, CE8: Block vector prediction for CPR (test 8.1.1a and test 8.1.1b), J. Nam, J. Lim, S. Kim (LGE)
  + JVET-M0333, Non-CE8: Coding on block vector difference, J. Nam, J. Lim, S. Kim (LGE)
  + JVET-M0334, Non-CE8: Removal of redundant syntax between CPR and other inter coding tools, J. Nam, J. Lim, S. Kim (LGE)
  + JVET-M0335, Non-CE8: modification on SbTMVP process regarding with CPR, H.Jang, J.Nam, S.Kim, J.Lim(LGE)
  + JVET-M0336, Non-CE11: Considering boundary strength on CPR coded block boundary, H.Jang, J.Nam, S.Kim, J.Lim(LGE)
  + JVET-M0341, Non-CE8: MMVD harmonization with CPR, H.Jang, J.Nam, S.Kim, J.Lim(LGE)
  + JVET-M0393, Non-CE8: chroma block vector initialization for CPR in dual tree, T. Poirier, F. Le Léannec, F. Galpin (Technicolor)
  + JVET-M0402, Non-CE8: Proposed Cleanup for Current Picture Referencing, B. Heng, M. Zhou, W. Wan (Broadcom)
  + JVET-M0407, CE8: CPR reference memory reuse without increasing memory requirement (CE8.1.2a and CE8.1.2d), X. Xu, X. Li, S. Liu (Tencent), E. Chai (Ubilinx)
  + JVET-M0408, CE8: CPR reference memory reuse with reduced memory requirement (CE8.1.2b and CE8.1.2c), X. Xu, X. Li, S. Liu (Tencent), E. Chai (Ubilinx)
  + JVET-M0409, Non-CE8: Mismatch between text specification and reference software on ATMVP candidate derivation when CPR is enabled, X. Xu, X. Li, S. Liu (Tencent), W.-J. Chien, M. Karczewicz (Qualcomm)
  + JVET-M0410, Non-CE8: CPR flag signaling at slice level, X. Xu, X. Li, S. Liu (Tencent)
  + JVET-M0411, Non-CE8: Inter mode related flag signaling when current picture is the only reference picture, X. Xu, X. Li, S. Liu (Tencent)
  + JVET-M0418, CE8-related: Context modeling on pred\_mode\_flag when current picture is the only reference picture (CPR), Yu-Chen Sun, Jian Lou (Alibaba)
  + JVET-M0474, CE8.1.3: Extended CPR reference with 1 buffer line, L. Pham Van, V. Seregin, W.-J. Chien, T. Hsieh, M. Karczewicz (Qualcomm)
  + JVET-M0483, CE8-related: CPR mode signaling and interaction with inter coding tools, W.-J. Chien, V. Seregin, M. Karczewicz (Qualcomm)
  + JVET-M0541, Non-CE8: Combination of MMVD and CPR mode, Y. Li, Z. Chen (Wuhan Univ.), X. Xu, S. Liu (Tencent)
  + JVET-M0542, Non-CE8: Combination of Multi Hypothesis Intra and CPR mode, Y. Li, Z. Chen (Wuhan Univ.), X. Xu, S. Liu (Tencent)
  + JVET-M0544, Non-CE8: CPR with chroma 4x4 sub-block size when dual-tree is on, X. Xu, X. Li, S. Liu (Tencent)
* Palette related:
  + JVET-M0050, Palette Mode in HEVC (test 8.2.1), Yu-Chen Sun, Jian Lou (Alibaba), Yung-Hsuan Chao, Hongtao Wang, Vadim Seregin, Marta Karczewicz (Qualcomm)
  + JVET-M0051, CE8: Palette Mode and Intra Mode Combination (test 8.2.2), Yu-Chen Sun, Jian Lou (Alibaba)
  + JVET-M0052, CE8: Separate Palette Coding for Luma and Chroma (test 8.2.5), Yu-Chen Sun, Jian Lou (Alibaba), Yung-Hsuan Chao, Hongtao Wang, Vadim Seregin, Marta Karczewicz (Qualcomm), Roman Chernyak, Sergey Ikonin, Jianle Chen (Huawei)
  + JVET-M0417, CE8-related: Combination test of CE8.2.2 and CE8.2.5, Yu-Chen Sun, Jian Lou (Alibaba)
  + JVET-M0419, CE8-related: Context modeling on palette mode flag, Yu-Chen Sun, Jian Lou (Alibaba)
  + JVET-M0455, CE8: Palette index map scan order constraints (Test 8.2.3), J. Ye, X. Xu, M. Xu, X. Li, S. Liu (Tencent)
  + JVET-M0456, CE8: palette mode when dual-tree is enabled (Test 8.2.4), J. Ye, X. Xu, X. Li, S. Liu (Tencent)
  + JVET-M0457, CE8: Palette predictor list enhancement (Test 8.2.6), J. Ye, X. Xu, M. Xu, X. Li, S. Liu (Tencent)
* Other:
  + JVET-M0056, CE8: BDPCM with LOCO-I and independently decodable areas (test 8.3.1a), F. Henry, A. Mohsen (Orange), P. Philippe, G. Clare (bcom)
  + JVET-M0057, CE8: BDPCM with horizontal/vertical predictor and independently decodable areas (test 8.3.1b), F. Henry, M. Abdoli (Orange), P. Philippe, G. Clare (bcom)
  + JVET-M0058, CE8: BDPCM with modified binarization (test 8.3.2), F. Henry, M. Abdoli (Orange), G. Clare, P. Philippe (bcom)
  + JVET-M0253, Non-CE8: Hash-based Motion Search, J. Xu, J. Li, K. Zhang, L. Zhang (Bytedance), R. Xiong (Peking University)
  + JVET-M0365, Non-CE3: modified PDPC for horizontal and vertical modes, A. Filippov, V. Rufitskiy, J. Chen (Huawei)
  + JVET-M0449, CE8-related: BDPCM entropy coding with reduced number of context coded bins, M. Xu, X. Li, X. Xu, M. Gao, S. Liu (Tencent)
  + JVET-M0464, Non-CE8: Unified Transform Type Signalling and Residual Coding for Transform Skip, B. Bross, T. Nguyen, P. Keydel, H. Schwarz, D. Marpe, T. Wiegand (HHI)

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, and to continue evaluating new and modified test materials and consider including some of them in class F

See the notes for AHG3 relating to a desire to improve the SCC test sequences.

[JVET-M0012](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5405) JVET AHG report: High-level parallelism and coded picture regions (AHG12) [T. Ikai, M. M. Hannuksela, R. Sjöberg, R. Skupin, W. Wan, Y.-K. Wang, S. Wenger]

The document summarizes activities of AHG on High-level parallelism and coded picture regions between the 12th and the 13th JVET meetings.

Related contributions to this meeting were categorized as follows:

* Flexible size tiles
  + JVET-M0066 AHG12: Flexible Tile Partitioning, Y. Yasugi, T. Ikai (Sharp)
  + JVET-M0423 Cross-check of JVET-M0066: AHG12: Flexible Tile Partitioning, A. Wieckowski (HHI)
  + JVET-M0376 AHG12: On signalling of flexible tiles, M. Damghanian, R.Sjöberg, M. Pettersson (Ericsson)
  + JVET-M0459 AHG12: On tiles with partial CTUs, R. Skupin, K. Suehring, Y. Sanchez, T. Schierl (HHI)
  + JVET-M0527 AHG12: Comments on Tiles and Flexible Tile Partitioning, W. Wan, M. Zhou, T. Hellman, B. Heng, P. Chen (Broadcom)
  + JVET-M0530 is also related to the flexible tile size.
* Tile partitioning and signaling (extraction also related)
  + JVET-M0121 AHG12: On Rectangular Tile Group, Y. He, A. Hamza (InterDigital)
  + JVET-M0123 AHG12: On hierarchical tile design, Y. He, A. Hamza (InterDigital)
  + JVET-M0129 AHG12: On flexible tiling, Y.-K. Wang, Hendry, M. Sychev (Huawei)
  + JVET-M0130 AHG12: On tile grouping, Y.-K. Wang, Hendry, J. Chen, M. Sychev (Huawei)
  + JVET-M0134 AHG12: On explicit signalling of tile IDs, Hendry, Y.-K. Wang, J. Chen, M. Sychev (Huawei)
  + JVET-M0137 AHG12: On tile configuration signaling, M. Sychev, Hendry, Y.-K. Wang (Huawei)
  + JVET-M0160 AHG17: Flexible tile grouping for VVC, L. Chen, T.-D. Chuang, Y.-W. Huang, S.-M. Lei (MediaTek)
  + JVET-M0261 AHG12: On grouping of tiles, M. M. Hannuksela, A. Aminlou (Nokia)
  + JVET-M0373 AHG12: Merge friendly tile group address signaling, R.Sjöberg, M. Damghanian, M. Pettersson (Ericsson)
  + JVET-M0374 AHG12: Flexible tiles to support MCTS use cases, R.Sjöberg, M. Damghanian, M. Pettersson (Ericsson)
  + JVET-M0375 AHG12: On uniform tile spacing, M. Damghanian, R.Sjöberg, M. Pettersson (Ericsson)
  + JVET-M0388 AHG12/AHG17: On merging of MCTSs for viewport-dependent streaming. M. M. Hannuksela (Nokia)
  + JVET-M0416 AHG12: On Tile Information Signalling, S. Deshpande (Sharp)
  + JVET-M0430 AHG12: On Tiles and Tile Groups for VVC, R. Skupin, K. Suehring, Y. Sanchez, T. Schierl (HHI)
  + JVET-M0530 AHG12: On signalling of tiles, M. Coban, M. Karczewicz (Qualcomm)
* Motion constraint tile (inter) and high level signalling
  + // MCTS
    - JVET-M0136 AHG12: Treating tile and tile group boundaries as picture boundaries, J. Chen, Y.-K. Wang, Hendry, M. Sychev (Huawei)
    - JVET-M0445 AHG12: On motion constrained tiles for VVC, R. Skupin, V. George, K. Suehring, Y. Sanchez, T. Schierl (HHI)
  + // Nal unit level signalling
    - JVET-M0155 AHG12: On tile group identification for VVC, B. Choi, S. Wenger, S. Liu (Tencent)
    - JVET-M0536 AHG12: On picture-level tiles and sequence-level tiles for VVC, E. Thomas, A. Gabriel (TNO)
* Wrap around tile (intra)
  + JVET-M0209 AHG12: On tile group configuration, W. Choi, K. Choi, K. Choi (Samsung)
* Specific tool changes for tile
  + JVET-M0300 CE4-related: HMVP and parallel processing with tiles and tile groups, A. M. Kotra, J. Chen, B. Wang, S. Esenlik, H. Gao (Huawei)
  + JVET-M0325 CE8-related: CPR with previous CTU availability at frame and tile edge, C. Rosewarne, A. Dorrell (Canon) – Later withdrawn
* WPP related
  + JVET-M0070 AHG12: Wavefront processing in a tile group, T. Ikai, S. Deshpande, T. Chujoh, E. Sasaki, T. Aono (Sharp)
  + JVET-M0071 AHG12: Improved parallel processing capability with WPP, Y. Fujimoto, M. Ikeda, T. Suzuki (Sony)
  + JVET-M0593 Crosscheck of JVET-M0071 (AHG12: Improved parallel processing capability with WPP), Y. Yasugi, T. Ikai (Sharp)

The AHG recommended to review the related contributions.

[JVET-M0013](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5554) JVET AHG report: Tool reporting procedure (AHG13) [W.-J. Chien, J. Boyce, R. Chernyak, R. Hashimoto, Y.-W. Huang, S. Liu, D. Luo]

This document summarizes the activity of AHG13: “Tool reporting procedure” between the 12th Meeting in Macao, CN (3–12 Oct. 2018) and the 13th meeting in Marrakech, MA (9–18 Jan. 2019). Tool on/off experimental results vs. VTM anchor are provided for the tools specified in JVET-L1005.

The initial version of JVET-L1005 “Methodology and reporting template for tool testing” was provided on Oct 27th. The document contained a reporting template.

All tests described in JVET-L1005 were conducted, except 67IPM and PDPC. VTM tool tests were conducted on VTM-3.0 software with VTM configuration by switching off specific tool either in configuration files or macros. Tool tests of 67IPM and PDPC were not conducted because there was no associated configuration setting nor associated macros in VTM-3.0 in order to disable the coding tools.

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

[add notes]

For two topics, testing was not performed because this part of the design could not be disabled in the software:

* 67 intra prediction mode +6 MPM intra mode coding + Wide angle intra prediction
* Position dependent prediction combination

It was remarked that decisions need to be made regarding which features can be disabled, and it is difficult to measure the benefit for a feature if it cannot be turned off. See also the AHG15 report on this topic.

[Integrate glossary terms]

[JVET-M0014](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5545) JVET AHG report: Progressive intra refresh (AHG14) [J.-M. Thiesse, A. Duenas, K. Kazui, A. Tourapis]

This document summarizes activities of AhG on progressive intra refresh between the 12th and 13th JVET meetings.

An AHG14 kick-off email was sent on 17 December 2018.

A Gitlab repository had been setup for the AHG participants (https://vcgit.hhi.fraunhofer.de/jvet-l-ahg-14/VVCSoftware\_VTM). The software based on VTM 3.0 with changes proposed in contributions JVET-M0197 and JVET-M0387 was shared in respective branches for review by participants.

Relevant contributions to this meeting were identified as follows:

* JVET-M0197 “AHG14: Software for ultra low-latency encoding“, K. Kazui (Fujitsu).
* JVET-M0387 “AHG14: Updates on Intra Refresh Proposal”, J.-M. Thiesse, D. Gommelet, D. Nicholson (Vitec).
* JVET-M0529 “AHG14: Normative Recovery Point Indication”, M. Pettersson, R. Sjöberg, M. Damghanian (Ericsson).

The AhG recommended to:

* Review all related contributions.
* Combine all proposed software modifications in AHG software (a Gitlab branch).
* Agree on common test conditions for progressive intra refresh.
* Integrate the encoder-only modifications in the next VTM.

[JVET-M0015](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5544) JVET AHG report: Bitstream decoding properties signalling (AHG15) [J. Boyce, J. Chen, S. Deshpande, M. Karczewicz, A. Tourapis, Y.-K. Wang, S. Wenger]

This AHG report was not available when the meeting began, so its consideration was deferred. As the report indicated little activity, it was not discussed in detail but was made available for consideration.

This document summarizes the activity of AHG15: Bitstream decoding properties signaling, between the between the 12th meeting in Macao, CN (3–12 October 2018) and the 13th meeting in Marrakech, MA, 9–18 January 2019.

There was no email activity on the reflector for this AHG during this period. Although when the AHG was established, a phone conference call was indicated as a possibility, but because of lack of activity, no phone conference call was held. One related contribution was noted in the AHG report:

* JVET-M0451 Update to interoperability point syntax [J. Boyce (Intel)]

The AHG recommended to:

* Review contributions
* Consider high-level syntax location(s) for tool restriction syntax

[JVET-M0016](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5209) JVET AHG report: Implementation studies (AHG16) [M. Zhou, J. An, E. Chai, K. Choi, S. Sethuraman, T. Hsieh, X. Xiu]

This document summarizes the activity of AHG16: implementation studies, between the 12th JVET meeting in Macao, CN (3-12 October 2018) and the 13th JVET meeting in Marrakech, MA (9–18 January 2019).

There were not many email exchanges on the main JVET email reflector (jvet@lists.rwth-aachen.de) with an [AHG16] indication on message headers. A summary of the AHG activities was provided as follows:

Feedback provided during the finalization of CE descriptions:

* Multiple hypothesis inter prediction (MHIP): It was suggested to test coding efficiency impact after the line buffer for motion vectors of the additional hypotheses is removed and the total number of distinct reference frames is constrained to 2 for the hypotheses. This is captured in the CE10 description.
* Decoder-side motion vector refinement (DMVR): It was suggested to take the following elements as the baseline DMVR algorithm, i.e.
  + Block sizes for DMVR W\*H=64 && H>=8 && W\*H<=1024
  + Reference block size (w+7)\*(h+7) (for luma)
  + Integer DMVR
  + MV mirroring between list0 and list1 to allow bilateral matching
  + 25 points SAD-based integer-pel search (i.e. +/− 2 refinement search range)
  + “Parametric error surface equation” based sub-pel refinement
  + Refined MVs used for MC only
  + Luma/chroma MC w/ reference block padding (if needed)

Additional tests were recommended to quantify the benefits of the following DMVR elements in the context of VTM3.0:

* + Mean removed SAD (MRSAD)
  + Bilateral interpolation
  + Use of the refined MVs from the top neighboring CTUs for merging/AMVP/TMVPs/de blocking
  + and splitting a large block to multiple of 16x16 sub-blocks for the DMVR
  + The suggestion above is integrated into in the CE9 description.
* Bi-directional optical flow (BDOF aka. BIO): It was commented that it is desirable to avoid the processing irregularity in the extended area during the prediction block generation for the BIO. In the current design the bilinear filters are used in the extended area. If the 8-tap MC filters are consistently used for the prediction block generation including the extended area, the reference block padding should be used to avoid memory bandwidth increase. Such a test is already planned in CE9.
* Overlapped motion compensation (OBMC): It was suggested to test OBMC when current block is uni-prediction and the neighboring blocks only use uni-prediction to generate OBMC region. When testing sub-block OBMC combined with affine mode, it is suggested to only do blending for top one line and left one column without doing blending for right column and bottom line. Such tests are planned in CE10.
* Current picture referencing (CPR, aka. IBC): It was commented that sharing the line buffer in the de-blocking filter for IBC will likely lead to the local memory increase (to avoid memory access conflicts between the de-blocking and the IBC). This is generally agreed and reflected in the final CE8 description.
* Planar motion vector prediction (PMVP): It was commented that using 8x8 sub-block size (or 8x8 for bi-pred and 8x4/4x8 for uni-pred) is most relevant for the CE tests. It is also desirable to avoid further stressing the merging list derivation process and signal the PMVP mode separately (as opposed to signaling it as an additional merging candidate. This comment might be valid for the regression based motion vector field (RMVF) too). Such tests are planned in CE2.

Other general comments

* Flexible tiling has a profound impact on block-level decoder implementation and should be carefully studied. Potential implications include the increased VDPU processing rate, the increased memory bandwidth if tiling is not VDPU aligned vertically, the increased buffering for frame compression, for in-loop filters and for TMVP storage, and the increased VDPU memory addressing overhead.
* (Affine) merging/AMVP list derivation is a block by block sequential operation within a CTU. Throughput study is needed to make sure that the current VTM3.0 design meets the throughput requirement (e.g. cycle budget of ~50 cycles per 8x8 block for 4K@60 at ~400 MHz clock rate).
* Separate luma/chroma partitioning tree introduces a long latency for chroma intra prediction when the CCLM is on. In the worst case, the chroma intra prediction cannot be kicked off until the whole 64x64 luma block is reconstructed (e.g. when a 64x64 luma block is split horizontally while the chroma blocks are split vertically, and vice versa). Suggest quantifying the gain of separate tree on the top of CCLM to see whether the CCLM and the separate tree can be made mutually exclusive.
* 2x2 Chroma intra-prediction itself is a serious concern from the throughput and processing overhead point of view, given the fact that the CCLM made the luma/chroma intra-prediction sequential, the luma intra prediction has been made more complicated (e.g. 4-tap interpolation filters, PDPC), and the combined intra/inter prediction was already adopted into the intra prediction/reconstruction critical path. It is helpful to test whether the CCLM can be disabled for 4x4 PUs.
* New tools such as diffusion filters, local illumination compensation (LIC), Hadamard transform domain/bilateral filtering of reconstructed blocks, and combined intra/inter prediction are all in the critical path of the intra prediction/reconstruction loop. Given the CCLM, PDPC and combined intra/inter prediction that are already adopted, the additional tools that could be absorbed into this loop is likely very limited from the throughput point of view. Therefore, the benefits of those tools should be carefully studied against each other.
* Line buffer removal from the Adaptive Loop Filter (ALF) is a significant cost reduction which should be pursued.
* The current design of the Bi-directional optical flow (BDOF aka. BIO) prohibits the 64x64 based decoder pipeline due to the early termination which requires a SAD computation up to 128x128 block size.
* 32x32/32x16/16x32 DST7/DCT8 based transform units are the bottleneck for the implementation of primary transforms.
* Transform coefficients “Zero out” of large TUs (e.g. 64x64/32x64/64x32) should be enforced at the syntax-level to avoid unnecessary CABAC context storage on the decoder side.
* Combination of Current Picture Referencing (CPR, aka. IBC) with other tools requires careful thinking. CPR combinations with triangle prediction, bi-prediction, weighted prediction, GBI prediction, BDOF and OBMC will require replication of those motion compensation logics into the intra prediction/reconstruction block. Moreover, using other tools (e.g. MMVD) to signal a CPR vector or using the CPR vectors as neighboring spatial and/or temporal candidates may further complicate the logic of the (affine) merging/AMVP list derivations due to additional CPR-related checks.

Broadcom conducted a memory bandwidth study on multiple hypothesis inter prediction by running both the CE software provided by HHI and the VTM3.0 with a commercial motion compensation cache model integrated. The summary results of the random access configuration are provided in the Table 1 and Table 2 (for informational purposes).

The following contributions were identified as relevant to the AHG.

* JVET-M0527, “AHG12: Comments on Tiles and Flexible Tile Partitioning” [W. Wan, M. Zhou, T. Hellman, B. Heng, P. Chen (Broadcom)]
  + Elaborated the potential implications of the flexible tiling on decoder designs.
* Contributions aiming for addressing the 64x64 decoder pipeline issue of the BDOF (aka. BIO)
  + JVET-M0284, “CE9-related: BDOF Modifications to Enable 64x64 VPDU” [H. Chen, X. Ma, S. Esenlik, H. Yang, J. Chen (Huawei)]
  + JVET-M0073, “Non-CE9: On early termination for BIO” [K. Kondo, M. Ikeda, T. Suzuki (Sony)]
  + JVET-M0249”, Non-CE9: Modifications on Bi-Directional Optical Flow” [H. Liu, L. Zhang, K. Zhang, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]
* Contributions relating to ALF line buffer reduction
  + JVET-M0164, “Adaptive loop filter with virtual boundary processing” [C.-Y. Chen, T.-D. Chuang, Z.-Y. Lin, C.-Y. Lai, Y.-W. Huang, S.-M. Lei (MediaTek)]
  + JVET-M0301, “Non-CE: Loop filter line buffer reduction” [A. M. Kotra, S. Esenlik, B. Wang, H. Gao, J. Chen (Huawei)]
* Contributions aiming to prohibit the transform coefficients from being transmitted in the “zero-out” regions of 64x64/64x32/32x64 transform units at the syntax level
  + JVET-M0250, “Non-CE7: Simplified CSBF coding for large block-size transforms” [J. Choi, J. Heo, S. Yoo, J. Choi, L. Li, J. Lim, S. Kim (LGE)]
  + JVET-M0257, “CE7-related: coefficient scanning and last position coding for TUs of greater than 32 width or height” [M. Coban, M. Karczewicz (Qualcomm)]
* Contributions relating to CPR vector usage and CPR combination with other tools
  + JVET-M0402, “Non-CE8: Comments on Current Picture Referencing” [B. Heng, M. Zhou, W. Wan (Broadcom)]
  + JVET-M0175, “CE8-related: Clarification on interaction between CPR and other inter coding tools” [C.-Y. Lai, T.-D. Chuang, Y.-L. Hsiao, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]
  + JVET-M0483, “CE8-related: CPR mode signaling and interaction with inter coding tools” [W.-J. Chien, V. Seregin, M. Karczewicz (Qualcomm)]
* JVET-M0046, “CE6-related: A study of primary transforms” [M. Zhou, Y. Hu (Broadcom)]
  + Identified the 32-point DST7/DCT8 as a bottleneck for the implementation of primary transforms and recommended a “zero-out” solution.
* JVET-M0245, “AHG16-related: Chroma block coding and size restriction” [C. Rosewarne, A. Dorrell (Canon)]
  + JVET-M0065 Non-CE: Intra chroma partitioning and prediction restriction [T. Zhou, T. Ikai (Sharp)]
  + Removal of 2x2/2x4/4x2 block sizes from the chroma intra prediction (for the separate tree case only)
* JVET-M0248, “AHG16: Motion compensation with padded samples for small coding units” [H. Liu, J. Chon, H.-C. Chuang, L. Zhang, K. Zhang, J. Xu (Bytedance)]
  + Memory bandwidth reduction for motion compensation of small size PUs.
  + There are many other contributions in this category.
* JVET-M0265, “AHG16: Clean-up on MV Rounding” [K. Zhang, L. Zhang, H. Liu, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]
  + Discusses design consistency of the MV rounding.

The AHG recommended reviewing the input contributions.

[JVET-M0017](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5394) JVET AHG report: High-level syntax (AHG17) [R. Sjöberg, S. Deshpande, M. M. Hannuksela, R. Skupin, Y.-K. Wang, S. Wenger]

This document summarizes the activities of the AHG on High-level syntax (HLS) between the 12th JVET meeting in Macao, CN (3-12 Oct. 2018) and the 13th meeting in Marrakech, MA (9-18 Jan. 2019).

No e-mail related to AHG17 was sent to the JVET reflector during the AHG period except a kick-off message.

It was reported that the amount of input contributions related to the mandates of this AHG has increased from 8 in Macau to 22 for this meeting. For the wider category of high-level syntax contributions including AHG12, AHG14, AHG15 and AHG17, the number of input contributions is reported to have increased from 28 in Macau to 50 for this meeting. Note that the count differs from the JVET-M\_Notes\_d0.docx categorization in which 49 documents are allocated to section 6.19 “High-level syntax”.

It is reported that of the 12 JCT-VC meetings where the first version of HEVC was developed, the first 6 meetings had fewer high-level syntax contributions than this JVET meeting and the last 6 had a higher number with a peak of 96 of high-level syntax contributions at the 11th meeting in Stockholm 2012.

The number of documents in the high-level syntax category has increased from 8 to 50 in two meeting cycles.

22 of the input documents registered by January 7 were identified as related to the mandates of this AHG.

* JVET-M0101 AHG17: On VVC HLS [R. Skupin, K. Suehring, Y. Sanchez (HHI),M. M. Hannuksela, K. Kammachi-Sreedhar (Nokia), Y.-K. Wang,Hendry (Huawei), S. Wenger, B. Choi (Tencent),S. Deshpande (Sharp)]
* JVET-M0120 AHG17: Proposed NAL Unit Header Design Principles [S. Wenger, B. Choi, S. Liu (Tencent)]
* JVET-M0128 AHG17: On reference picture management for VVC [Y.-K. Wang, Hendry (Huawei), S. Deshpande (Sharp), M. M. Hannusela (Nokia), G. Ryu, W. Choi (Samsung), X. Wang, Y.-W. Chen (Kawi), L. Zhang (Bytedance), P. Wu, M. Li (ZTE), S.-H. Kim (LG), J. Boyce (Intel), A. M. Tourapis, D. Singer (Apple), F. Edouard, P. Andrivon (Technicolor), Y.-W. Huang, C.-W. Hsu, C.-Y. Chen, T.-D. Chuang, L. Chen (MediaTek), K. Kawamura (KDDI), Y.-C. Sun, J. Lou (Alibaba)]
* JVET-M0131 AHG17: On NAL unit types for IRAP pictures and leading pictures [Y.-K. Wang, Hendry (Huawei)]
* JVET-M0132 AHG17: On header parameter set (HPS) [Y.-K. Wang, Hendry, J. Chen (Huawei)]
* JVET-M0133 AHG17: On parsing dependency between parameter sets [Y.-K. Wang (Huawei), J. Boyce (Intel)]
* JVET-M0152 AHG17: On random access point for VVC [B. Choi, S. Wenger, S. Liu (Tencent)]
* JVET-M0153 AHG17: On leading picture for VVC [B. Choi, S. Wenger, S. Liu (Tencent)]
* JVET-M0154 AHG17: On decoded picture buffer management for VVC [B. Choi, S. Wenger, S. Liu (Tencent)]
* JVET-M0156 AHG17: On component type indication for VVC [B. Choi, S. Wenger, S. Liu (Tencent)]
* JVET-M0157 AHG17: On picture order count for VVC [B. Choi, S. Wenger, S. Liu (Tencent)]
* JVET-M0160 AHG17: Flexible tile grouping for VVC [L. Chen, T.-D. Chuang, Y.-W. Huang, S.-M. Lei (MediaTek)]
* JVET-M0161 AHG17: Signalling random access properties in the NAL unit header [L. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]
* JVET-M0260 AHG17: Carriage of tile group header parameters in higher level structures [M. M. Hannuksela (Nokia)]
* JVET-M0377 AHG17: Picture header NAL unit type [R. SjÃ¶berg, M. Damghanian, M. Pettersson (Ericsson)]
* JVET-M0378 AHG17: RPS for VVC [R. SjÃ¶berg, M. Damghanian, M. Pettersson (Ericsson)]
* JVET-M0386 AHG17: On slice\_type (tile\_group\_type) [K. Suehring, Y. Sanchez, R. Skupin (HHI)]
* JVET-M0388 AHG12/AHG17: On merging of MCTSs for viewport-dependent streaming [M. M. Hannuksela (Nokia)]
* JVET-M0415 AHG17: Comments on High-Level Syntax of VVC [S. Deshpande (Sharp)]
* JVET-M0520 AHG17: On NAL unit header design for VVC [S. Wenger, B. Choi, S. Liu]
* JVET-M0537 AHG17: On signaling of tile group set with MCTS properties (NAL unit header and new parameter set) [E. Thomas, A. Gabriel (TNO)]
* JVET-M0579 On Frame Rate Support and Extraction in VVC [A. Segall, S. Deshpande (Sharp Labs of America), M. Hannuksela (Noka)]

It was noted that at some point in the HEVC development, we started having AHG pre-meetings for HLS work.

The AHG recommended reviewing the related input contributions and to continue to study VVC high-level syntax aspects.

# Project development (10)

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

## Text and general standard development (0)

## Software development (1)

[JVET-M0055](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4857) AHG3: VTM transcoding capabilities for bitrate matching and debugging [T. Hinz, A. Wieckowski (HHI)]

Presented Thu 8:40pm. Chaired by FJB

The VTM contains extensions allowing for effective trouble-shooting by faster debugging as well as alternative capabilities for bitrate matching. Both of these functionalities are implemented by incorporating the decoder into the encoder, effectively allowing transcoding of existing bit streams, possibly switching to actual encoding at a predefined point. The purpose of this document is to highlight those capabilities, including a short documentation, as well as to propose a further extension allowing to switch between transcoding and encoding with per-CTU rather than per-frame granularity.

Usage should be documented in VTM SW package (to be added as mandate to AHG3).

Decision (SW): adopt

## Common test conditions (1)

CPR in CTC?

[Ensure reflected in notes: CPR and hash search enabled for class F. This hash search is for ordinary inter, not just CPR. CPR also has a hash search, but a different one.]

[JVET-M0090](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4893) On the use of chroma QP offsets in the VVC common test conditions [C. Helmrich, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

Discussed ~2200 Thursday 17 January (GJS & F. Bossen).

Since version 2 of the VTM reference software for the Versatile Video Coding (VVC) standard, chroma QP offsets of value 1 have been used for testing according to the common test conditions (CTC), but only in (Intra) frames for which dual-tree coding has been enabled. This contribution reports that, in comparison with the HEVC reference software, HM 16.x, the current VTM 3.x version provides much higher BD-rate gains in the chromatic than in the luminance channel. To counteract this uneven distribution of the coding gain, which was found to be perceptually questionable, it is recommended to revert the CTC settings to the use of chroma QP offsets of 1 not only in dual-tree frames but in all frames. Note that this modification has virtually no effect on the all-Intra (AI) coding configuration (only the frame headers change by one bit).

Currently:

* for the all-Intra (AI) configuration, the BD-rate gain in chroma is about 7% higher than that in luma,
* for the random-access (RA) configuration, the gain in chroma is about 11% higher than that in luma.

As proposed:

* for the AI configuration, the BD-rate gain in chroma remains 7% higher than the gain in luma,
* for the RA configuration, the gain in chroma now is about 5–6% higher than the gain in luma.

A comment was to consider low QP.

In some experiments, the contributor found that it was also perceptually better to increase the chroma QP offset.

With this change, we would also no longer have a different setting for different frame types.

Decision (CTC): Adopt (effect is AI: no change, RA: 1% benefit for luma 8% degradation for chroma, LB: 0.8% benefit for luma and 17% degradation for chroma).

## Coding studies on specific use cases (8)

Contributions on this topic were discussed in Track A Monday 14 January 2015-2240 (GJS).

[JVET-M0135](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4940) On adaptive resolution change (ARC) for VVC [Hendry, Y.-K Wang, J. Chen (Huawei), T. Davies, A. Fuldseth (Cisco), Y.-C Sun, T.-S Chang, J. Lou (Alibaba)]

This contribution discusses use cases or application scenarios that would benefit from an adaptive resolution change (ARC) capability where the spatial resolution may change at a non-IRAP picture. Then a preliminary design of ARC as is presented and suggested to be a place-holder just to trigger the discussion. It is proposed that the support of ARC for VVC is discussed, and if there is sufficient interest, either start a CE or include aspects of ARC support as one or more mandates of an AHG.

The need to switch may be motivated by wanting to reduce bit rate – being required to send an I frame is obviously a problem for that purpose.

* Rate adaption in video telephony and conferencing
* Active speaker change in multi-party video conferencing
* Fast start in streaming
* Adaptive stream switching in streaming

The basic tools constraints for supporting ARC are as follows:

* The spatial resolution may differ from the nominal resolution by a factor 0.5, applied to both dimensions. The spatial resolution may increase or decrease, yielding scaling ratios of 0.5 and 2.0.
* The aspect ratios and chroma formats of the video format are not changed.
* The cropping areas are scaled in proportion to spatial resolutions.
* The reference pictures are simply re-scaled as needed and inter prediction is applied as usual.

It is proposed to use simple, zero-phase separable down- and up-scaling filters. Note that these filters are for prediction only; a decoder may use more sophisticated scaling for output purposes.

The following 1:2 down-scaling filter is used, which has zero phase and 5 taps:

( −1, 9, 16, 9, −1 ) / 32

The down-sampling points are at even sample positions and are co-sited. The same filter is used for luma and chroma.

For 2:1 up-sampling, additional samples at odd grid positions are generated using the half-pel motion compensation interpolation filter coefficients in the latest VVC WD.

The combined up- and down-sampling will not change phase or the position of chroma sampling points.

This can be considered a coding efficiency feature (esp. for *subjective* benefit).

A suggested alternative was spatial pre-filtering in the encoder while sending a higher resolution. This could be tested as an alternative. The technique known as “reduced resolution update” was also noted as an alternative.

It was commented that this would also be a natural element of scalable coding. With this an reference picture selection, this is basically all that is needed to support spatial scalability.

Further study in an AHG was encouraged. See also M0259.

[JVET-M0259](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5066) Use cases and proposed design choices for adaptive resolution changing (ARC) [M. M. Hannuksela, A. Aminlou (Nokia)]

The following is high-level design choices are proposed for VVC version 1:

1. It is proposed to include a reference picture resampling process in VVC version 1 for the following use cases:

* Usage of efficient prediction structures (e.g. so-called open groups of pictures) in adaptive streaming without compromising from the fast and seamless representation switching capability between representations of different properties, such as different spatial resolutions.
* Adapting low-delay conversational video content to network conditions and application-originated resolution changes without significant delay or delay variation.

1. The VVC design is proposed to allow merging of a sub-picture originating from a random-access picture and another sub-picture originating from a non-random-access picture into the same coded picture conforming to VVC. This is asserted to enable efficient handling of viewing orientation changes in mixed-quality and mixed-resolution viewport-adaptive 360° streaming. This design choice is discussed also in JVET-M0388.
2. It is proposed to include sub-picture-wise resampling process in VVC version 1. This is asserted to enable efficient prediction structure for more efficient handling of viewing orientation changes in mixed-resolution viewport-adaptive 360° streaming.

Section 5.13 ("Support for Adaptive Streaming") of MPEG N 17074 includes the following requirement for VVC:

The standard shall support fast representation switching in the case of adaptive streaming services that offer multiple representations of the same content, each having different properties (e.g. spatial resolution or sample bit depth). The standard shall enable the use of efficient prediction structures (e.g. so-called open groups of pictures) without compromising from the fast and seamless representation switching capability between representations of different properties, such as different spatial resolutions.

The contribution suggested that using this with a CRA picture can provide a gradual quality change.

See also the prior JCT-VC contribution JCTVC-F158 (T. Davies/Cisco) July 2011.

Region-wise mixed resolution encoding, including the use of MCTSs, was described. Using the region-wise packing SEI message with MCTSs can provide mixed-resolution view-port dependent streaming for 360° video content and is described in an informative annex of OMAF.

It was commented that DASH has something called stream structure ID that supports stream switching without resolution change.

Further study in an AHG was encouraged. See also M0135.

[JVET-M0360](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5167) Video coding based on cross RAP referencing (CRR) [H. Yu, X. Gao, Q. Yuan, X. Lin, L. Yu (Zhejiang Univ.), Y. Fan, Y. Zhao, H. Yang, Y.-K. Wang, J. Chen (Huawei)] [late]

This contribution proposes an approach to allow inter prediction referencing across random access points (RAPs), referred to as cross RAP referencing (CRR). Simulation results reportedly show BD coding gains in the range from 11.21% to 25.91% based on VTM3.0 in VVC CTC and from 19.6% to 37.38% based on HM16.15 in HEVC CTC. A brief description of signalling, decoding process, and random access operations is provided. It is proposed to start a CE on this.

The idea of a “library picture” provided by external (unicast) means and referenced across what are otherwise random access points was described.

This scheme does not have any “drift”.

It was noted that the DRAP of an HEVC SEI message (see JCTVC-S0095) has a close relationship to this.

Impact on syntax? It was remarked that, with system support for managing the library, this seems possible with the current syntax (e.g., using long-term reference pictures – possibly more than one of them).

System support would be required no matter what, as the system needs to deliver the library pictures.

Possibly some property indicator could be used to assist – e.g., an SEI message that just indicates that no following pictures in decoding and/or output order will refer to any previous pictures in decoding that are not in the RPS of the current picture.

Further study in an AHG was encouraged to study the properties of such an approach and determine whether this or similar functionality would need to have some impact on the syntax or decoding process. Such an impact does not seem strictly necessary for basically achieving this usage, given appropriate systems support, but may be determined helpful in some way in further study. It was suggested for systems experts to also study this and determine whether file-format / DASH / other system support should be specified for this sort of usage.

[JVET-M0855](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5686) Crosscheck of JVET-M0360 (Video coding based on cross RAP referencing (CRR)) [H. Liu (Bytedance)] [late]

[JVET-M0514](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5325) Removal of CIP from Multi-hypothesis Intra Prediction [C.-C. Chen, W.-J. Chien, M. Karczewicz (Qualcomm)]

Presented Thu 6.30pm. Chaired by FJB

This report proposes to remove the constrained intra prediction (CIP) from multi-hypothesis intra prediction (MHIntra). Specifically, the CIP flag does take effect on the derivation process of reference samples when MHIntra flag is on. It is reported that the proposed method reduces the Y/U/V BD-rate loss from VTM-3.0 with CIP=1 by 0.83%/0.44%/0.43% for Random Access and 0.93%/2.01%/2.09% for Low Delay B.

No CIP in current design, and no agreement to add it.

No action at this time.

[JVET-M0667](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5488) Crosscheck of JVET-M0514 (Removal of CIP from Multi-hypothesis Intra Prediction) [J. Li, C. S. Lim (Panasonic)] [late]

[JVET-M0197](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5004) AHG14: Software for ultra low-latency encoding [K. Kazui (Fujitsu)]

Presented Thu 6.50pm. Chaired by FJB

This contribution proposes software modifications for integrating encoder-only progressive intra refresh in the VTM model, in accordance with the mandates of AHG14 “Progressive intra refresh”. The proposed software modifications are the use of flexible tile partitioning in JVET-M0066 [5] and the methods described in JVET-L0079 “AHG14: Study of methods for progressive intra refresh” [4].

Version 2 contains two additional test results. First one is the comparison with low-delay B. Second one is the comparison with the proposal with normative changes.

Each CTU row is partitioned into 2 tiles, a “refreshed” tile and a “not-refreshed tile”



Significant overhead: +29% for LDB (RA results incomplete)

Suggests some normative changes to make overhead disappear.

Proposes to use provided SW for future AHG14 experiments.

No action.

AHG14 to consider / decide use of software. Could be uploaded to AHG14 space on Gitlab.

[JVET-M0387](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5194) AHG14: Updates on Intra Refresh Proposal [J.-M. Thiesse, D. Gommelet, D. Nicholson (VITEC)] [late]

This contribution reports an update of the software modifications for the study of progressive intra refresh (used in AHG 14). This code has been made available in the AHG Gitlab repository (see the AHG14 report). Both encoder-only modifications and a normative solution have been reported to VTM 3.0.1 with handling of new tools adopted at the Macao meeting. The corresponding performance is reportedly in the same range as the results presented at the Macao meeting, with a loss of 21.29% in average for the encoder-only modifications against a low-delay B reference with a comparable intra period of 32 for classes B, C and E. The normative proposal reportedly brings an improvement of approximately 5.26% (test results for classes C and E; class B data not available) against an encoder-only modification solution by adding identify the position of the intra refresh area and then exploit this position for decoding process.

Test conditions were proposed for further AHG activity.

It was also proposed to integrate the proposed encoder-only modifications for intra-refresh support on VTM 4.

In the proposed normative approach, there is a disabling of the loop filter at the boundary of the refresh area and avoidance of MVs that reference potentially corrupted samples. Tiles can be used with disabling of the loop filter at tile boundaries.

The proposal used whole-picture encoding. It was asked whether that is appropriate for what is intended as ultra-low-delay operation. This implies a whole picture latency.

The refresh was not using whole-CTU refresh; it was using CU-level intra. It was saving the sending of a couple of CU-level flags based on a signalled width for the refresh region. There was discussion of whether that aspect is desirable and provides any meaningful bit rate savings by itself.

It was suggested to consider thicker refresh regions, perhaps not spanning the whole picture vertically. This would present a much less severe restriction on motion vectors. Using an adaptive-size region was also suggested.

Part of the measured gain seems to be based on the use of a fine-granularity refresh area.

The application usage was discussed. Suggested applications were multicast real-time communication, video gaming, surveillance, drone video, remote driving, remote display.

It did not yet seem fully clear whether the proposed method is appropriate and the testing conditions are reasonable.

[JVET-M0871](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5702) AHG14: Performance Evaluation by CTU based Intra Refresh [K. Kawamura, S. Naito (KDDI)] [late]

Orally presented Thu 6.30pm. Chaired by FJB

This contribution reports the performance evaluation by CTU based intra refresh approach as information. While the anchor condition candidate in JVET-L0160 used a CU line as a granularity of the refresh area, this contribution used a CTU line. For 1080p content, CTU size is set to 64 instead of 128 to realize that the intra refresh period becomes 30 frames. The preliminary simulation results shows 7.4% Y-BD rate loss compared to with / without intra refresh coding condition. This contribution also suggests to change the intra refresh period to 30 frame, instead of 32 frame.

For information only. No action.

[JVET-M0466](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5275) Adaptive Streaming Test Conditions for VTM [M. Afonso, A. Norkin, A. Aaron, J. Sole, K. Swanson (Netflix), Y. Ye, W. Jiang (Alibaba), J. Kim, K. Kolarov, D. Singer, A. Tourapis (Apple)]

TBP.

Presented Thu 7.05pm. Chaired by FJB

This document describes a proposal for an additional set of test conditions to be included in the Common Test Conditions (CTC), referred to as Adaptive Streaming Random Access (AS-RA). The test conditions proposed are intended to simulate a video streaming scenario, which is characterized by the availability of multiple streams of the same video content at the server side, obtained by an offline encoding of the input video at distinct bitrates/qualities/resolutions. The goal of the proposed test conditions is to cover this important use case, currently missing in the CTC, with less than 50% of the computational cost of the current Random Access CTC for classes A1/A2 and B.

Option 1:

AS-RA test conditions: encode same sequence 4 times at different combinations of resolutions and QP (combinations are sequence-dependent).

+44% total run time increase

Option 2:

MR-RA test conditions: encode same sequence 16 times at different combinations of 4 resolutions and 4 QP values (combinations are same for each sequence), and take convex hull.

+171% total run time increase

SHVC filters for up and downsampling. It was commented that different filters may give slightly different results.

It was mentioned that closed GOPs are used (instead of open GOPs in current RA configuration).

Unclear whether this would bring new information that would lead to different decisions on a tool-by-tool basis.

Should be further studied before making any changes to CTC.

Could make sense to run this metric for each major VTM release. Netflix volunteered to do it for VTM 4.0. Include in AHG13? mandate.

Further study encouraged, e.g. test on tool-by-tool basis.

## Test material (0)

# Core Experiments

## CE1: Partitioning (3)

[JVET-M0021](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5395) CE1: Summary report on partitioning [J. Ma, F. Le Léannec, M. W. Park]

This contribution was discussed on Wednesday 9 January 1530–1700 (GJS).

This document evaluates CE1: Partitioning JVET-L1021. There were two tests that were conducted by proponents and cross-checked by at least one cross-checker. There were no mismatches reported to the coordinators.

The current VTM Software has split restrictions implemented to allow 64x64 pipelining. More precisely, the concept of (square shaped) virtual pipelining data units (VPDUs) is used to allow for 64x64 pipelining inside the picture.

The software for both tests can be found here

https://vcgit.hhi.fraunhofer.de/JVET-L-CE1/VVCSoftware\_VTM.git

SubCE1.1.1

(JVET-M0446, Tencent)

Proponents study non square VPDUs to enhance RD-performance and unify with boundary partitioning of the current VTM software.

Conditions for CU\_TRIH\_SPLIT and CU\_TRIV\_SPLIT are changed so that, e.g. 128x32 and 32x128 block sizes are possible. Sub-partitions of such blocks are also allowed. However, 128x64 and 64x128 are not allowed to be split using a ternary split whereas 128x128 can be split using a ternary split. Results do not effect AI.

|  |  |  |  |
| --- | --- | --- | --- |
| **#** | **Tester** | **Comments** | **Cross-checkers** |
| 1.1.1 | M. Xu (Tencent) | The cross-checkers (CC) generally confirm the simulation results and the matching of the implementation with the CE description. Mismatches for encoder timings were reported as follows:  LDB 110% (CC) vs 105% (proponent).  Further comment/suggestions were made by CC:   * Formulate the constraints in a more general way, e.g. instead of not allowing a ternary split for 128x64 and 64x128, the proponents can constraint the size by 2MAX\_TU\_SIZE\_FOR\_PROFILE x MAX\_TU\_SIZE\_FOR\_PROFILE * It should be considered how many extra partitions would be supported if using rectangular VPDUs mixed with squared VPDUs instead of only squared VPDUs. * More details on the latency impact of using different VPDU shapes are desired. For example, in Figure 1 two cases are compared: First: all 64x64 VPDU structures vs Second: First four 32x128 VPDUs and then four 64x64 VPDUs.  Now VPDU4 in case 1 of the figure below would have less pipeline dependency and latency issues if data from VPDU1 is used compared to case 2 of the figure below were data from VPDU3 is always used. * Interest for interactions with other tools such as CPR/WPP were expressed. | C. W. Hsu (MediaTek) |



Example for different VPDU structures. Numbers denote the processing order of VPDUs

While the cross-checker indicated that case 2 had more cases where the immediately previous decoded region was needed for prediction (e.g., intra prediction) than case 1. The proponent indicated that the worst case was the same in both cases. And if what matters is average rather than worst case, case 2 would be more rarely encountered.

It was suggested that the key test sequences for this issue are the high resolution ones, since there is generally little gain for using very large blocks with low-resolution test sequences.

The VTM uses 64x64 VPDUs (for luma). The proposal tries to get coding efficiency by allowing rectangular shapes 32x128/128x32.

In the current draft spec, these rectangular shapes are available for the edge of the picture.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra Main 10** | | | | | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
|  | **Over VTM-3.0** | | | | | **Over VTM-3.0** | | | | | **Over VTM-3.0** | | | | |
|  | Y | U | V | EncT | DecT | Y | U | V | EncT | DecT | Y | U | V | EncT | DecT |
| Class A1 | 0.00% | 0.00% | 0.00% | 97% | 98% | -0.48% | -0.48% | -0.42% | 117% | 99% |  |  |  |  |  |
| Class A2 | 0.00% | 0.00% | 0.00% | 101% | 100% | -0.48% | -0.37% | -0.31% | 110% | 99% |  |  |  |  |  |
| Class B | 0.00% | 0.00% | 0.00% | 99% | 100% | -0.17% | -0.17% | -0.24% | 110% | 100% | -0.15% | -0.65% | -0.09% | 105% | 96% |
| Class C | 0.00% | 0.00% | 0.00% | 100% | 100% | 0.00% | 0.00% | -0.03% | 104% | 102% | -0.01% | 0.26% | 0.19% | 102% | 98% |
| Class E | 0.00% | 0.00% | 0.00% | 102% | 101% |  |  |  |  |  | -0.54% | -1.06% | -1.41% | 109% | 96% |
| **Overall** | 0.00% | 0.00% | 0.00% | 100% | 100% | -0.25% | -0.23% | -0.23% | 110% | 100% | -0.20% | -0.45% | -0.33% | 105% | 97% |
| Class D | 0.00% | 0.00% | 0.00% | 100% | 101% | 0.02% | -0.12% | -0.09% | 102% | 102% | -0.01% | 0.31% | 0.22% | 100% | 100% |
| Class F | 0.00% | 0.00% | 0.00% | 100% | 100% | -0.11% | -0.11% | -0.04% | 108% | 102% | -0.17% | -0.15% | -0.25% | 102% | 99% |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Low delay P Main10** | | | | |
|  |  | **Over VTM-3.0** | | |  |
|  | Y | U | V | EncT | DecT |
| Class A1 |  |  |  |  |  |
| Class A2 |  |  |  |  |  |
| Class B | -0.14% | 0.00% | 0.07% | 106% | 96% |
| Class C | 0.03% | 0.14% | -0.34% | 101% | 100% |
| Class E | -0.49% | -0.87% | -0.91% | 109% | 101% |
| **Overall** | -0.17% | -0.17% | -0.31% | 105% | 99% |
| Class D | 0.01% | -0.40% | -0.36% | 101% | 101% |
| Class F | -0.07% | -0.40% | -0.72% | 102% | 101% |

The proponent highlighted the benefit of 0.5% for Class A in RA configuration.

Further simulation results are available in JVET-M0446 including:

* Simulations without some VTM encoder speedups (0.48% becomes 0.54% benefit for Class A in RA configuration)
* Simulations for limiting the VTM to not use 32x128/128x32 partitions at boundaries (0.06% penalty in RA configuration)

It was commented that the coding efficiency benefit of the proposal comes with a substantial encoder search penalty (~13%) and a similar increase in encoder search complexity without changing the syntax/decoding process would also provide some coding efficiency benefit.

It was suggested that removing the special treatment of the edges without adding support for alternative VPDU shapes seemed to be the likely outcome.

This was further discussed Thursday 17 January 1500 (GJS) after simulations completed to measure the penalty for for limiting the VTM to not use 32x128/128x32 partitions at boundaries. See also the related contributions M0888 and M0905. There had been some bug in the original test results for M0446. After fixing that, M0446 is proposing the same scheme as proposed in M0888 method 1 and in M0905.

Decision (cleanup/consistency): Adopt inferred QT split to avoid 32x128/128x32 partitions at picture boundaries (0.06% penalty in RA configuration).

SubCE1.2.1

(JVET-M0236, Canon)

Proponents extend current TU tiling such that TUs do not cross the boundaries of a 64x64 grid. It is also proposed that by using this technology the ternary split at the top level becomes available and therefore an improved RD-performance is possible.

Conditions for TU\_MAX\_TR\_SPLIT are changed such that each resulting TU is contained in a single 64x64 region on a 64x64 grid. This is obtained by using smaller TUs than what is currently being used in the VTM software. For instance, by allowing the ternary split at the top level a 64x128 center block arises which is then tiled into four 64x32 TUs to match the constraint. Results do not effect AI.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra Main10** | | | | | **Random Access Main 10** | | | | | | | | **Low delay B Main10** | | | | | | | |
|  | **Over VTM-3.0** | | | | | **Over VTM-3.0** | | | | | | | | **Over VTM-3.0** | | | | | | | |
|  | Y | U | V | EncT | DecT | Y | | U | | V | | EncT | DecT | Y | | U | | V | | EncT | DecT |
| Class A1 | 0.00% | 0.00% | 0.00% | 102% | 106% | -0.52% | | -0.71% | | -0.50% | | 132% | 98% |  | |  | |  | |  |  |
| Class A2 | 0.00% | 0.00% | 0.00% | 100% | 103% | -0.66% | | -0.59% | | -0.45% | | 123% | 100% |  | |  | |  | |  |  |
| Class B | 0.00% | 0.00% | 0.00% | 100% | 102% | -0.28% | | -0.26% | | -0.24% | | 122% | 101% | -0.20% | | -0.47% | | 0.03% | | 118% | 97% |
| Class C | 0.00% | 0.00% | 0.00% | 100% | 103% | -0.03% | | -0.05% | | 0.00% | | 113% | 104% | 0.00% | | 0.24% | | -0.12% | | 106% | 107% |
| Class E | 0.00% | 0.00% | 0.00% | 99% | 99% |  | |  | |  | |  |  | -0.70% | | -0.61% | | -0.40% | | 123% | 99% |
| **Overall** | 0.00% | 0.00% | 0.00% | 100% | 103% | -0.34% | | -0.36% | | -0.27% | | 122% | 101% | -0.26% | | -0.27% | | -0.13% | | 115% | 101% |
| Class D | 0.00% | 0.00% | 0.00% | 96% | 105% | -0.05% | | -0.08% | | -0.03% | | 113% | 105% | 0.00% | | 0.29% | | 0.21% | | 103% | 96% |
| Class F (optional) | 0.00% | 0.00% | 0.00% | 100% | 102% | -0.17% | | -0.22% | | -0.16% | | 120% | 101% | -0.35% | | -0.21% | | -0.36% | | 110% | 104% |

Remarks:

* The gain is substantial (0.59% for Class A in RA configuration)
* There is a substantial encoder complexity increase (~27%)
* This has a latency issue for decoding, since the TU coefficient data needs to be buffered up for VPDU pipeline processing. A related contribution M0237 proposes to shift this buffering burden to the encoder.

No action was taken on this.

Related proposals M0195 and M0285 allows PUs to straddle the VPDU boundaries but requires there to be no residual in those cases (0.38% benefit for Class A in RA configuration with encoder complexity increase of 19% if allowing all modes with zero residual, or 0.2% benefit for Class A in RA configuration with encoder complexity increase of 5% if allowing only skip mode in these cases). No action was taken on these as well.

[JVET-M0236](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5043) CE1: Transform tiling for pipelined processing of CTUs (Test 1.2.1) [C. Rosewarne, A. Dorrell (Canon)]

[JVET-M0446](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5255) CE1: Rectangular virtual pipeline data unit (test 1.1.1) and supplementary results [M. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0856](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5687) Cross-check of JVET-M0446: CE1: Rectangular virtual pipeline data unit (test 1.1.1) and supplementary results [A. Wieckowski (HHI)] [late]

## CE2: Subblock motion compensation (24)

Contributions in this category were discussed Wednesday 9 Jan. 1540–2100 and Thursday 10 Jan. 0900-1100 (in Track B chaired by JRO).

[JVET-M0022](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5386) CE2: Summary report on sub-block based motion prediction [Y. He, C.-Y. Chen, C.-C. Chen]

The goal of Core Experiment 2 (CE2) is to investigate sub-block based motion prediction techniques on top of VTM-3.0. It comprises 5 categories,

* CE 2.1: Affine motion compensation
* CE 2.2: Affine merge mode
* CE 2.3: Sub-block based merge mode
* CE 2.4: Complexity reduction
* CE 2.5: ATMVP and related topics

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.

CE2.1: Affine motion compensation

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 2.1.1 | Adaptive precision for affine MVD coding:  a{1-pel,1/4-pel,1/4-pel}, b{1/4-pel,1/4-pel,1/4-pel}, c{1/8-pel,1/8-pel,1/8-pel} | JVET-M0420 |
| 2.1.2 | Adaptive MVD precision for affine inter mode coding: {1-pel,1-pel,1-pel}, {1/4-pel,1/4-pel, 1/4-pel}, {1/16-pel,1/16-pel,1/16-pel} | JVET-M0246 |

The numbers are referring to {top-left,top-right,bottom-left}

Current affine uses 1/4 pel precision for signalling, but 1/16 pel precision in sub-blocks; affine merge uses 1/16 pel (but does not need to signalling)

Both tests use signalling and are only modifying affine MV coding, merge is unchanged. Test 2.1.1 uses 1 flag to signal 1/4 (case b) or not, and 1 flag to signal (if not) if it is a or c. Test 2.1.2 re-uses the adaptive MV precision signalling (but with 2 additional contexts) for affine, and also uses switching 1/16,1/4, 1 pel (instead 1/4, 1, 4 pel) precision.

The method comes with increase in encoder runtime, whereas decoder complexity increase is marginal (some additional logic and 2 contexts)

Method of 2.1.2 has slightly higher gain, and is assessed to be conceptually more straightforward, consistent with AMVR (it is however reported that by just reusing AMVR with same precision steps and same context coding, loss would occur).

The motion vector rounding is also consistent with the current design.

Decision: Adopt JVET-M0246 (Test 2.1.2), extending AMVR to affine. Use the AMVR high level flag for disabling both “normal” AMVR and “affine” AMVR.

Specification text was later provided and reviewed by B. Bross.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 2.1.1 | -0.19% | -0.08% | -0.12% | 105% | 101% | -0.13% | -0.16% | 0.04% | 106% | 100% |
| 2.1.2 | -0.23% | -0.21% | -0.27% | 104% | 99% | -0.20% | -0.08% | -0.30% | 112% | 100% |

CE2.2: Affine merge

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 2.2.1.a | Bypass Affine flag for Skip CU | JVET-M0380 |
| 2.2.1.b | CABAC context change for Affine Flag | JVET-M0380 |
| 2.2.2.a | 2 contexts: one for Affine and one for regular Merge index | JVET-M0381 |
| 2.2.2.b | 1 context: one for both Affine Merge index and regular Merge index | JVET-M0381 |
| 2.2.3.a | Applying affine HMVP candidates to affine merge | JVET-M0125 |
| 2.2.3.b | Applying affine HMVP candidates for affine motion vector prediction | JVET-M0125 |
| 2.2.3.c | Combined test of 2.2.3a and 2.2.3b | JVET-M0125 |
| 2.2.3.d | Replace existing inherited affine candidates with affine HMVP candidates | JVET-M0125 |
| 2.2.4.a | Affine merge with offset and block level signalling | JVET-M0431 |
| 2.2.4.b | Based on 2.2.4a, but offset value range depends on picture height | JVET-M0431 |
| 2.2.4.c | Based on 2.2.4b, but POC distance based offset mirroring for Bi-prediction | JVET-M0431 |
| 2.2.4.d | Based on 2.2.4b, but POC distance based offset scaling for Bi-prediction | JVET-M0431 |
| 2.2.5 | Affine MV offset merge candidates | JVET-M0476 |
| 2.2.6.a | Simplification for 6-param and 4-param constructed candidates by setting P = 3 in 7 availability cases | JVET-M0477 |
| 2.2.6.b | Simplification for 6-param and 4-param constructed candidates by setting P = 3 in 2 availability cases | JVET-M0477 |
| 2.2.7.a | “Low complexity” affine merge with temporal candidates (however, increases complexity compared to VTM, see notes below) | JVET-M0256 |
| 2.2.7.b | “Medium complexity” affine merge with temporal candidates (however, increases complexity compared to VTM, see notes below) | JVET-M0256 |
| 2.2.7.c | Withdraw |  |
| 2.2.7.d | Withdraw |  |
| 2.2.7.e | Withdraw |  |
| 2.2.8.a | In affine AMVP, apply some pruning on candidates. Rounding, clipping applied before pruning | JVET-M0282 |
| 2.2.8.b | In affine merge, apply some pruning on inherited candidates | JVET-M0282 |
| 2.2.8.c | 2.2.8.a + 2.2.8.b | JVET-M0282 |
| 2.2.8.d | 2.2.8.c + 4.1.5.c | JVET-M0282 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 2.2.1.a | 0.09% | 0.21% | 0.20% | 102% | 98% | 0.03% | 0.04% | 0.06% | 103% | 92% |
| 2.2.1.b | -0.01% | 0.02% | -0.01% | 100% | 100% | 0.00% | 0.02% | 0.06% | 99% | 98% |
| 2.2.2.a | 0.00% | 0.00% | -0.01% | 100% | 98% | 0.03% | -0.05% | 0.10% | 99% | 94% |
| 2.2.2.b | 0.07% | 0.04% | 0.06% | 100% | 104% | 0.05% | 0.03% | 0.15% | 100% | 96% |
| 2.2.3.a | -0.06% | -0.04% | -0.02% | 100% | 100% | -0.06% | 0.04% | 0.09% | 101% | 100% |
| 2.2.3.b | -0.01% | 0.01% | 0.02% | 100% | 100% | 0.00% | 0.00% | 0.09% | 102% | 101% |
| 2.2.3.c | -0.07% | -0.04% | -0.04% | 100% | 100% | -0.03% | -0.05% | -0.18% | 101% | 102% |
| 2.2.3.d | 0.07% | 0.10% | 0.06% | 100% | 100% | 0.09% | 0.09% | 0.02% | 101% | 101% |
| 2.2.4.a | -0.16% | -0.13% | -0.14% | 104% | 100% | 0.01% | -0.05% | -0.07% | 107% | 100% |
| 2.2.4.b | -0.17% | -0.12% | -0.13% | 104% | 100% | -0.02% | 0.09% | -0.04% | 106% | 100% |
| 2.2.4.c | -0.20% | -0.08% | -0.09% | 104% | 100% | 0.04% | -0.01% | 0.19% | 105% | 100% |
| 2.2.4.d | -0.20% | -0.09% | -0.09% | 104% | 99% | 0.02% | 0.07% | 0.07% | 106% | 99% |
| 2.2.5 | -0.06% | -0.02% | -0.05% | 104% | 101% | -0.03% | 0.06% | -0.03% | 105% | 99% |
| 2.2.6.a | 0.00% | 0.01% | -0.01% | 100% | 100% | 0.07% | -0.01% | 0.18% | 99% | 99% |
| 2.2.6.b | 0.02% | 0.04% | 0.00% | 100% | 100% | 0.08% | 0.14% | 0.04% | 99% | 98% |
| 2.2.7.a | -0.08% | -0.02% | -0.13% | 105% | 102% | -0.03% | -0.12% | -0.09% | 116% | 115% |
| 2.2.7.b | -0.10% | -0.10% | -0.14% | 106% | 102% | -0.07% | -0.21% | -0.08% | 117% | 116% |
| 2.2.8.a | 0.00% | 0.01% | 0.00% | 100% | 100% | -0.01% | 0.04% | -0.07% | 100% | 100% |
| 2.2.8.b | -0.01% | -0.01% | 0.00% | 101% | 100% | -0.03% | 0.00% | -0.05% | 100% | 100% |
| 2.2.8.c | -0.02% | 0.00% | 0.00% | 100% | 100% | 0.00% | 0.05% | 0.10% | 100% | 100% |
| 2.2.8.d | -0.04% | -0.01% | -0.01% | 100% | 100% | -0.03% | -0.12% | -0.17% | 100% | 100% |

Complexity analysis

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **AMVP/Merge list size** | **Max number of potential candidates** | **Max number of MV comp.** | **Max number of ref idx comp.** | **Max number of MV scaling** | **Max number of conditional cases to enable constructed candidates** | **Others** |
| 2.2.1.a | same | Same | Same | same | same | same |  |
| 2.2.1.b | same | Same | Same | same | same | same |  |
| 2.2.2.a | same | Same | Same | same | same | same |  |
| 2.2.2.b | same | Same | Same | same | same | same |  |
| 2.2.3.a | same | Merge +5 | Same | same | same |  | \*Affine HMVP 170 bytes |
| 2.2.3.b | same | AMVP + 2 | Same | +2 | same |  | \*Do ref index selection for affine HMVP based on the selected ref. in AMVP  \*Affine HMVP 68 bytes |
| 2.2.3.c | same | Merge +5 /  AMVP +2 | Same | +2 | same |  | \*Affine HMVP 170 bytes |
| 2.2.3.d | same | same | Same | -1 | same |  | Reduce CPMV buffer from 1296 bytes to 170 bytes. Note: 1296 bytes requires optimized affine CPMV buffer update. Otherwise, storage of a full CTU's CPMV needs 6192 bytes.  Position comp: merge + 5/AMVP +4 |
| 2.2.4.a | same | Same | Same | same | same | same |  |
| 2.2.4.b | same | Same | Same | same | same | same |  |
| 2.2.4.c | same | Same | same | same | same | same |  |
| 2.2.4.d | same | same | same | same | same | same |  |
| 2.2.5 | same | same | same | same | same | same |  |
| 2.2.6.a | same | -3 | -8 | -22 | same | same |  |
| 2.2.6.b | same | -3 | -8 | -22 | same | 2(-5) |  |
| 2.2.7.a | same | same | + 38 | -12 | +2 |  |  |
| 2.2.7.b | same | +3 | +98 | +26 | +3 |  |  |
| 2.2.8.a | same | same | +3 | same | same |  |  |
| 2.2.8.b | same | same | +6 | +2 | same |  |  |
| 2.2.8.c | same | same | +3 for AMVP +6 for Merge | +0 for AMVP +2 for Merge | same |  |  |
| 2.2.8.d |  |  |  |  |  |  |  |

2.2.1a has loss, but does not really solve a problem in terms of complexity

2.2.1b uses different neighbor positions (A1/B1) for the context of affine flag coding (which currently uses A2/B3), claiming that these are positions different from those used in merge. However, other elements (e.g. AMVR, triangular, quadtree/MTT split flag) use also A2/B3. Therefore, making this change only for affine flag does not seem to be a unification/simplification.

The current affine merge has 4 context coded bins. Both tests 2.2.2a/b reduce this to only one (as in normal merge mode), where 2.2.2a uses different contexts for affine and normal merge, whereas 2.2.2b uses the same. 2.2.2a has no loss in RA, very small loss in LB, whereas 2.2b also shows 0.07% loss in RA.

Decision: Adopt JVET-M0381 Test 2.2.2a (reducing number of context coded bins in affine merge). Text is available with the contribution.

2.2.3.x establishes a history-based motion vector prediction for affine, however the HMVP candidates are different (specifically collected from affine coded blocks) than in normal HMVP.

It is commented that no coordinates are used for a/b/c (which theoretically might lead to wrong model depending on distance)

a/b/c have additional complexity in list derivation and storage of history camdidates, which is not justified by the small (highest 0.07% for 2.2.3c)

2.2.3d is interesting as it reduces the need of local storage for spatial CPMV (control point motion vectors) and replaces CPMV by history-based candidates. It however also disables the inheritance at CTU boundaries, which is asserted to be the main reason for the loss of 0.07% (there are CE related contributions JVET-M0432, JVET-M0110, JVET-M0168, JVET-M0262, JVET-M0270) that tackle this issue in various ways. The approach should be further studied to solve the complexity reduction with less penalty in terms of compression performance.

Test 2.2.4.x signals offset for affine merge mode (applied to all CPMV). The method b based on picture height only provides small additional benefit. The method d has some additional complexity for scaling, without showing benefit over c (which just uses mirroring). Gain is on average between 0.16% (for a) and 0.20% for c/d, generally higher for high resolution sequences.

It was initilly recommended in track B to adopt JVET-M0431, test CE3-2.2.4c, but on top of 2.2.4a (using distance offsets 1/2, 1, 2, 4, and 8-pel as per table 2.1 of M0431). Add a high-level enabling flag.

Specification text was to be provided and reviewed.

This decision was later reverted. See the discussion of this topic in the notes of the plenary of Sunday 13 January in section 11.1. It was agreed that this should be further studied in a CE.

2.2.5 is a similar approach with same number of offset candidates (total 20), but supports larger offset values, and different combinations. Gives less compression benefit.

2.2.6.x reduce the number of constructed affine candidates from 6 to 3. However, loss of 0.07% is observed in LDB (where constructed candidates may be used more often). Furthermore, the study of AHG16 shows that affine merge is not the most critical path in VVC. Therefore, proposals which reduce complexity in this area should rather come with very low penalty in compression.

2.2.7.a removes “mixed” spatial-temporal constructed candidates, replacing them by pure temporal candidates. The total number of candidates is unchanged, but the list construction (pruning) becomes more complicated. Gain is 0.08%/0.03% for RA/LB

2.2.7b keeps the original candidates, and adds three more pure temporal candidates. The list construction (pruning) has significantly higher complexity than current VVC (almost 3x number of MV comparisons). Gain is 0.1%/0.07% for RA/LDB

Some of the reported gain may also be due to encoder changes. No good tradeoff of performance compared to additional complexity. Also reports increased encoder runtime.

2.2.8.x adds some pruning processes to affine MV prediction and merge modes. Benefit in terms of compression not obvious. (Note that the technology had more promising compression benefit before VTM3).

Sub-CE 2.3: Sub-block based merge mode

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 2.3.1.a.1 | Planar motion vector prediction (PMVP) as a single mode with the sub-block size setting: 8x4 for BI, 4x4 for UNI | JVET-M0104 |
| 2.3.1.a.2 | PMVP as a single mode with the sub-block size setting: 4x8 for BI, 4x4 for UNI |
| 2.3.1.a.3 | PMVP as a single mode with the sub-block size setting: Adaptive 8x4/4x8 for BI, 4x4 for UNI |
| 2.3.1.a.4 | PMVP as a single mode with the sub-block size setting: 8x8 for BI, 4x4 for UNI |
| 2.3.1.a.5 | PMVP as a single mode with the sub-block size setting: Adaptive 8x4/4x8 for BI and UNI |
| 2.3.1.a.6 | PMVP as a single mode with the sub-block size setting: 8x8 for BI and UNI |
| 2.3.1.b | Withdraw |
| 2.3.1.c | PMVP as a candidate in sub-block (affine) merge list |
| 2.3.1.d | Withdraw |
| 2.3.2.a | The threshold is set as 1 pixel for the sub-blocks inside the 4x16, 16x4 and 8x8 blocks | JVET-M0485 |
| 2.3.2.b | The threshold is set to 0 pixel for 4x16 and 16x4 blocks along vertical and horizontal directions, respectively; and the threshold is set as 1 pixel for the sub-blocks inside 8x8 blocks |
| 2.3.3.a | Regression-based Motion Vector Field (RMVF) as a separate merge mode as described in JVET-L0171 | JVET-M0302 |
| 2.3.3.b | 2.3.3.a + the RMVF-coded blocks are used for affine merge candidate inheritance |
| 2.3.3.c | 2.3.3.a + complexity reduction (i.e., lower number of neighboring motion information for RMVF parameter derivation) |
| 2.3.3.d | 2.3.3.b + 2.3.3.c |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 2.3.1.a.1 | -0.11% | -0.10% | -0.17% | 103% | 103% | -0.08% | 0.01% | 0.09% | 104% | 103% |
| 2.3.1.a.2 | -0.10% | -0.18% | -0.18% | 103% | 103% | -0.05% | 0.03% | 0.01% | 104% | 103% |
| 2.3.1.a.3 | -0.11% | -0.13% | -0.22% | 103% | 103% | -0.04% | -0.11% | -0.07% | 104% | 104% |
| 2.3.1.a.4 | -0.11% | -0.07% | -0.15% | 103% | 101% | -0.05% | -0.07% | -0.19% | 104% | 102% |
| 2.3.1.a.5 | -0.10% | -0.15% | -0.18% | 103% | 102% | -0.06% | 0.01% | 0.02% | 104% | 103% |
| 2.3.1.a.6 | -0.11% | -0.10% | -0.17% | 103% | 103% | -0.08% | 0.01% | 0.09% | 104% | 103% |
| 2.3.1.c | 0.08% | 0.12% | 0.06% |  |  | 0.07% | -0.01% | 0.22% |  |  |
| 2.3.2.a  (over VTM-3.0) | -0.12% | -0.18% | -0.21% | 104% | 107% | -0.08% | -0.05% | 0.05% | 106% | 112% |
| Over 2.3.1 |  |  |  |  |  |  |  |  |  |  |
| 2.3.2.b | -0.12% | -0.15% | -0.23% | 104% | 107% | -0.08% | 0.22% | 0.08% | 106% | 112% |
| Over 2.3.1 |  |  |  |  |  |  |  |  |  |  |
| 2.3.3.a | -0.18% | -0.17% | -0.26% | 105% | 102% | -0.02% | -0.10% | 0.09% | 106% | 102% |
| 2.3.3.b | -0.20% | -0.25% | -0.24% | 104% | 101% | -0.02% | 0.12% | 0.21% | 103% | 102% |
| 2.3.3.c | -0.19% | -0.13% | -0.19% | 105% | 102% | 0.01% | 0.05% | -0.03% | 106% | 101% |
| 2.3.3.d | -0.19% | -0.22% | -0.23% | 105% | 100% | 0.00% | 0.07% | -0.16% | 106% | 101% |

Test 2.3.1.a adds PMVP as a new mode to determine subblock vectors. 2.3.1.a3 imposes the same restrictions as current (non-affine) subblock MC. Low gain (around 0.1%), whereas encoder/decoder run time increases. The CE report does not have a detailed complexity analysis, but it can be asserted to be not insignificant, as MV scaling is necessary for each subblock.

Test 2.3.1.c puts PMVP as additional candidate into the affine merge list (but uses 8x8 subblocks) – therefore, loss is observed, probably as affine usually has 4x4 subblocks, and/or merge list size is reduced.

PMVP had 0.6% gain before, which is now down to 0.1%. This does not justify adding another subblock mode with additional processing.

Test 2.3.3 is about Regression-based Motion Vector Field (RMVF), where a set of maximum of 112 candidates is fed into the regression in case of a 128x128 block , or 7 candidates in case of an 8x8 block (each of which has to be scaled before). The derivation performs regression versus a 6-parameter affine model. 2.3.3a determines the subblock candidates (8x8 SB) directly, 2.3.3b puts them as a candidate for affine merge, and then uses it with 4x4 subblocks.

Tests c and d correspond to a and b, but reduce the number of input candidates to roughly half. Gain is around 0.2% for b, and 0.19% for c/d. This gain is much lower than reported originally (which was around 0.7%). Also the dependency of the regression on block size and number of candidates is of some concern (integer 16 bit, division-free). No precise analysis of complexity was made, but it is likely that the complexity of the regression (worst case of number of multiplications, availability checks, scaling operations, number of cycles) as used in the current CE would not justify adding another subblock mode, or an additional derivation of the affine model construction. Further study in CE to further reduce the number of candidates, and perform analysis of complexity impact.

Sub-CE2.4: Complexity reduction

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 2.4.1.a | 4x4 block is used as the sub-block size for a uni-directional affine coded CU while 8x4/4x8 block is used as the sub-block size for a bi-directional affine coded CU according to the width/height of the CU. | JVET-M0226 |
| 2.4.1.b | 4x4 block is used as the sub-block size for a uni-directional affine coded CU while 8x4 block is used as the sub-block size for a bi-directional affine coded CU. |
| 2.4.1.c | 4x4 block is used as the sub-block size for a uni-directional affine coded CU while 4x8 block is used as the sub-block size for a bi-directional affine coded CU. |
| 2.4.2 | Restricted motion vector field for affine mode. | JVET-M0309 |
| 2.4.3.a | Affine restrictions for the worst-case bandwidth reduction:  The worst-case bandwidth is bi-prediction of an INTER\_8x4/INTER\_4x8 block. (\*changes only luma) | JVET-M0150 |
| 2.4.3.b | The worst-case bandwidth is uni-prediction of an INTER\_4x4 block. (\*changes only luma) |
| 2.4.3.c | The worst-case bandwidth is bi-prediction of an INTER\_9x9 block. (\*changes only luma) |
| 2.4.4.a | Affine sub-block size restrictions: 8x4 for BI, 4x4 for UNI. (\* changes applied to both luma and chroma) | JVET-M0472 |
| 2.4.4.b | 4x8 for BI, 4x4 for UNI. (\* changes applied to both luma and chroma) |
| 2.4.4.c | Adaptive 8x4/4x8 for BI, 4x4 for UNI. (\* changes applied to both luma and chroma) |
| 2.4.4.d | 8x8 for BI, 4x4 for UNI. (\* changes applied to both luma and chroma) |
| 2.4.5.a | clip sub-block MVs in 8x8 block for UNI and BI prediction. | JVET-M0488 |
| 2.4.5.b | Withdraw. |
| 2.4.6 | Modified affine inheritance from above CTU. | JVET-M0054 |
| 2.4.7 | Size constrain for inherited affine motion prediction. | JVET-M0053 |
| 2.4.8 | Affine model inheritance with reduced memory requirement. | JVET-M0262 |
| 2.4.9 | Withdraw. |  |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 2.4.1.a | 0.11% | 0.10% | 0.09% | 100% | 99% | 0.10% | 0.12% | 0.11% | 101% | 97% |
| 2.4.1.b | 0.10% | 0.09% | 0.08% | 101% | 99% | 0.11% | 0.00% | 0.20% | 99% | 95% |
| 2.4.1.c | 0.12% | 0.07% | 0.09% | 99% | 96% | 0.13% | 0.16% | 0.16% | 99% | 95% |
| 2.4.2 | 0.01% | 0.00% | 0.05% | 101% | 100% | 0.01% | -0.05% | 0.07% | 101% | 100% |
| 2.4.3.a | -0.01% | 0.02% | 0.01% | 99% | 100% | 0.02% | -0.04% | -0.05% | 101% | 101% |
| 2.4.3.b | 0.27% | 0.14% | 0.18% | 97% | 98% | 0.27% | 0.22% | 0.08% | 99% | 100% |
| 2.4.3.c | 0.03% | 0.06% | 0.01% | 99% | 99% | -0.01% | -0.08% | -0.07% | 101% | 100% |
| 2.4.4.a | 0.10% | 0.09% | 0.08% | 99% | 99% | 0.11% | 0.00% | 0.20% | 98% | 98% |
| 2.4.4.b | 0.12% | 0.07% | 0.09% | 99% | 99% | 0.13% | 0.16% | 0.16% | 99% | 99% |
| 2.4.4.c | 0.11% | 0.10% | 0.09% | 99% | 99% | 0.10% | 0.12% | 0.11% | 99% | 99% |
| 2.4.4.d | 0.22% | 0.18% | 0.16% | 98% | 98% | 0.20% | 0.24% | 0.31% | 97% | 99% |
| 2.4.5.a | 0.01% | 0.00% | -0.03% | 100% | 100% | -0.02% | -0.10% | 0.06% | 102% | 103% |
| 2.4.6 | -0.01% | 0.01% | -0.02% | 100% | 100% | 0.02% | -0.03% | 0.02% | 100% | 99% |
| 2.4.7 | 0.02% | 0.02% | 0.03% | 100% | 100% | 0.05% | -0.11% | 0.05% | 100% | 99% |
| 2.4.8 | 0.00% | -0.02% | 0.02% | 100% | 99% | 0.03% | 0.15% | -0.04% | 100% | 103% |

Complexity analysis:

|  |  |  |  |
| --- | --- | --- | --- |
| **Test#** | **Bandwidth for uni/bi-prediction** | **Affine MVs storage** | **Others (additional operations for MV clipping or derivation, and so on.)** |
|
| Translational model | 6.25 / 8.56 |  |  |
| Affine model | 8.33 / 16.66 |  |  |
| 2.4.1.a | 8.33 / 11.84 | Same | 2 comparisons per CU  (1 for width/height + 1 for uni/bi) |
| 2.4.1.b | 8.33 / 11.84 | Same | 1 comparison per CU  (1 for uni/bi) |
| 2.4.1.c | 8.33 / 11.84 | Same | 1 comparison per CU  (1 for uni/bi) |
| 2.4.2 | 8.33 / 8.56 | Same | MV clipping for subblk MVs |
| 2.4.3.a | 8.33 / 11.84 | Same | 3 comparisons per CU  (1 for width/height + 1 for uni/bi + 1 for restriction) |
| 2.4.3.b | 8.33 /8.56 | Same | 1 comparison per CU  (1 for uni/bi) |
| 2.4.3.c | 8.33 / 9.53 | Same | 13 comparisons per CU (1 for uni/bi + 12 for restriction) |
| 2.4.4.a | 8.33 / 11.84 | Same | 1 comparison per CU  (1 for uni/bi) |
| 2.4.4.b | 8.33/11.84 | Same | 1 comparison per CU  (1 for uni/bi) |
| 2.4.4.c | 8.33 /11.84 | Same | 2 comparisons per CU (1 for width/height + 1 for uni/bi) |
| 2.4.4.d | 8.33 / 8.56 | Same | 1 comparison per CU  (1 for uni/bi) |
| 2.4.5.a | 4.77 / 9.53 | Same | MV clipping for subblk MVs + Find min every 4 subblk MVs (note: 9x9 luma) 14 comparisons for each 8x8 block |
| 2.4.6 | Same | Same | 4 POC comparisons |
| 2.4.7 | Same | 25% | Same |
| 2.4.8 | Same | 10 bit less per CU  ??% |  |

The following aspects are studied in this sub-CE:

1. Reduce worst case memory bandwidth for affine. This can be done either by disallowing 4x4 subblocks (Tests 2.4.1, 2.4.3b, 2.4.4). All these come with some penalty in compression performance (typically 0.1% when 4x8/8x4 SB are used for bi pred, 0.2+% when restriction 8x8 is used). It is noted that these approaches also reduce the number of computations for motion comp (more lines have to be interpolated at boundaries of 4x4 blocks before the vertical interpolation can be performed)

It is also mentioned that possible impact on visual quality might occur when using larger subblocks in afine MC, in particular for sequences with stronger affine motion. This has not been investigated yet

Other approaches (Tests 2.4.2, 2.4.3a/c, 2.4.5) keep 4x4 subblocks and impose some restrictions (e.g. by clipping, grouping, adaptive selection of subblock size based on CPMV), such that adjacent subblocks’ vectors are not too much different, and joint memory access could be made. These come with practically no loss in compression, but may require some additional logic. Keeping 4x4 subblocks and not losing compression performance appears the more desirable concept, but more study is necessary to understand the impact of different approaches how it can be achieved. The following aspects are important:

- Number of operations at decoder (for determining SB MVs and MC)

- More detailed study of worst case memory bandwidth in relation to memory access models, cache size, etc.

- Possibility of formulating by encoder/bitstream restrictions

- Possibility of applying such concepts not only for affine, but also for other small-size CU cases

- Possible impact on subjective quality

2. Reduction of local buffers for storing affine related CPMV inheritance (2.4.7, 2.4.8). 2.2.3.d is targeting the same issue. It appears from CE results (and possibly from CE related contributions) that this can be achieved by almost no loss in compression. However, also here more detailed analysis is necessary in terms of additional logic, and the effective saving in number of bits for local buffers.

Further analysis of the different approaches in BoG (Y. He), also review the CE related proposals, and suggest approaches to be further studied in upcoming CE. It is unquestionable that something is necessary in VVC to restrict the worst case memory bandwidth, but the optimum solution of achieving this may not be identified yet.

3. Sub-Test 2.4.6 enables 6-parameter model inheritance across CTU boundary. However in VTM3 this does not seem to have any benefit.

Sub-CE 2.5: ATMVP related

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 2.5.1 | Simplification of ATMVP, add additional CU size restriction (>64) | JVET-M0165 |
| 2.5.2.a | Withdraw | JVET-M0227 |
| 2.5.2.b | Withdraw |
| 2.5.2.c | Insert the new ATMVP into the affine merge candidate list in additional to the original ATMVP for non-low-delay picture with pruning |
| 2.5.2.d | Withdraw |
| 2.5.2.e | Withdraw |
| 2.5.2.f | Withdraw |
| 2.5.2.g | Withdraw |
| 2.5.2.h | For non-low-delay picture, insert the new ATMVP; for low-delay picture, insert VTM-3.0 ATMVP |
| 2.5.3.a | Withdraw |  |
| 2.5.3.b | Withdraw |  |
| 2.5.4 | Non-sub-block ATMVP | JVET-M0086 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 2.5.1 | 0.00% | 0.00% | 0.05% | 100% | 100% | 0.00% | -0.04% | 0.08% | 100% | 101% |
| 2.5.2.c | -0.04% | -0.07% | -0.06% | 100% | 101% | 0.00% | 0.00% | 0.00% | 100% | 100% |
| 2.5.2.h | 0.26% | 0.14% | 0.15% | 101% | 101% | 0.00% | 0.00% | 0.00% | 100% | 99% |
| 2.5.4 | 0.19% | 0.28% | 0.26% | 100% | 99% | 0.52% | 0.52% | 0.66% | 101% | 97% |

2.5.2.x is adding something without showing benefit any more on top of VTM3.

For 2.5.4, it is not obvious that the restriction is necessary (e.g., there is no memory bandwidth problem) – it generates loss. Further, there may be some interdependency with subblock boundary deblocking that was added in VTM3, so the subjective issue of ATMVP which might have occurred with VTM2 is no longer relevant.

2.5.1 is a simplification for subblock merge (including affine) by using it only for subblocks where no side is smaller than 8 (which is an existing condition), and the area shall be larger than 64 samples (which disallows 8x8 blocks. There is no loss in performance. However, there is no real problem in implementing 8x8 blocks, so this restriction seems unnecessary.

(include summaries of contribution from JVET-M0022 subsequently)

[JVET-M0053](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4855) CE2.4.7 Size constrain for inherited affine motion prediction [H. Huang, W.-J. Chien, M. Karczewicz (Qualcomm)]

[JVET-M0054](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4856) CE2.4.6 Modified affine inheritance from above CTU [H. Huang, W.-J. Chien, M. Karczewicz (Qualcomm)]

[JVET-M0104](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4909) CE2.3.1: Planar Motion Vector Prediction [N. Zhang, X. Chen, J. Zheng, Y. Lin (HiSilicon)]

[JVET-M0125](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4930) CE2: History Based Affine Motion Candidate (Test 2.2.3) [J. Zhao, S. Kim (LGE), G. Li, X. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0150](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4957) CE2.4.3: Affine restriction for worst-case memory bandwidth reduction [L. Pham Van, W.-J. Chien, H. Huang, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-M0664](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5485) Crosscheck of JVET-M0150 [S. Jeong, K. Choi (Samsung)] [late]

[JVET-M0165](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4972) CE2.5.1: Simplification of SbTMVP [C.-C. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0226](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5033) CE2.4.1: Reducing worst-case memory bandwidth of affine mode [Y.-W. Chen, X. Wang (Kwai Inc.)]

[JVET-M0227](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5034) CE2.5.2: A second ATMVP candidate [Y.-W. Chen, X. Wang (Kwai Inc.)]

[JVET-M0246](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5053) CE2: Adaptive Motion Vector Resolution for Affine Inter Mode (Test 2.1.2) [H. Liu, K. Zhang, L. Zhang, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-M0256](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5063) CE2: Affine temporal constructed candidates (test 2.2.7) [F. Galpin, A. Robert, F. Le Léannec, T. Poirier (Technicolor)]

[JVET-M0699](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5521) Crosscheck of JVET-M0256 (CE2: Affine temporal constructed candidates (test 2.2.7)) [H. Huang (Qualcomm)] [late]

[JVET-M0262](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5069) CE2: Affine model inheritance from single-line motion vectors (Test 2.4.8) [K. Zhang, L. Zhang, H. Liu, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-M0282](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5089) CE2: Affine motion predictor pruning (test 2.2.8) [A. Robert, F. Le Léannec, T. Poirier, F. Galpin (Technicolor)]

[JVET-M0302](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5109) CE2: Merge Mode with Regression-based Motion Vector Field (Test 2.3.3) [R. Ghaznavi-Youvalari, A. Aminlou, J. Lainema (Nokia)]

[JVET-M0309](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5116) CE2: Memory bandwidth reduction for affine mode (test 2.4.2) [J. Li, R.-L. Liao, C. S. Lim (Panasonic)]

[JVET-M0380](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5187) CE2: Affine Merge flag coding (Test 2.2.1) [G. Laroche, C. Gisquet, P. Onno, J. Taquet (Canon)]

[JVET-M0381](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5188) CE2: On Subblock Merge index coding (Test CE2.2.2) [G. Laroche, C. Gisquet, P. Onno, J. Taquet (Canon)]

[JVET-M0420](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5229) CE2: Adaptive precision for affine MVD coding (Test 2.1.1) [J. Luo, Y. He, X. Xiu (InterDigital)]

[JVET-M0431](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5240) CE2: Affine merge with prediction offset (Test CE2.2.4) [G. Li, X. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0472](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5282) CE2: Affine sub-block size restrictions (Test 2.4.4) [H. Chen, T. Solovyev, H. Yang, J. Chen (Huawei)]

[JVET-M0476](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5286) CE2: Control point MV offset for Affine merge mode (Test 2.2.5) [Y.-C. Yang, Y.-J. Chang (Foxconn)]

[JVET-M0477](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5287) CE2: Simplification of Affine constructed merge candidates (Test 2.2.6) and supplementary results [Y.-C. Yang, Y.-J. Chang (Foxconn)]

[JVET-M0798](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5629) Crosscheck of supplementary results of JVET-M0477 (CE2: Simplification of Affine constructed merge candidates (Test 2.2.6) and supplementary results) [H. Liu (Bytedance)] [late]

[JVET-M0485](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5295) CE2: Sub-block MV clip in planar motion vector prediction (test 2.3.2) [M. Gao, X. Li, M. Xu, S. Liu (Tencent)]

[JVET-M0488](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5298) CE2: Sub-block MV clip in affine prediction (test 2.4.5) [M. Gao, X. Li, M. Xu, S. Liu (Tencent)]

## CE3: Intra prediction and mode coding (16)

[JVET-M0023](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4901) CE3: Summary report on intra prediction and mode coding [G. Van der Auwera, J. Heo, A. Filippov]

This contribution was discussed Wednesday 9 January 1750–2030 (GJS)

This is the summary report of the third Core Experiment (CE3). The goal of CE3 is to study intra prediction tools, including mode coding, for potential inclusion into the VVC standard.

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

* CE3.1: Intra prediction modes (5 tests)
* CE3.2: Cross-component prediction (11 tests)
* CE3.3: Intra mode coding (10 tests)

This document summarizes the objective results (BD-rates, runtimes), cross-check reports, and related input contributions.

The source codes of the tests and full test results are uploaded by proponents into the following CE3 GitLab repository:

https://vcgit.hhi.fraunhofer.de/JVET-L-CE3/VVCSoftware\_VTM.git

The following changes were made to the CE3 test description document after the T2 deadline (December 6, 2018) had passed. Besides changes to contact persons and assignment of cross-checkers, the following changes were requested on the JVET reflector and discussed for clarification, if needed:

* CE3.2:
  + Added test CE3.2.2.1 (MMLM; combination of tests CE3.2.1 and CE3.2.2)
  + Added test CE3.2.6.2 (CCLM; testing 3 columns of neighbouring samples on left side of block, 1 row above block)
* CE3.3:
  + Reduction and clarification of test CE3.3.1 from 7 subtests to 4 (decoder-side intra mode derivation)
  + Additional result for test 3.5 (multiple DM for chroma)

CE3.1 on ‘Intra prediction modes’

|  |  |  |
| --- | --- | --- |
| **Test #** | **Description** | **Doc. #** |
| 1.1.1 | Intra sub-partitions coding mode (conceptually similar to prior “short-distance intra prediction”) with a different trade-off between gain and encoding run-time (at least 16 samples per partition; 2 or 4 partitions) | JVET-M0102 |
| 1.1.2 | Test 1.1.1 with a restriction: the resulting partitions must have a width of at least 4 samples (but height can be 1, 2, or 4) |
| 1.2.1 | Affine linear weighted intra prediction modes with encoder speedup | JVET-M0043 |
| 1.2.2 | Affine linear weighted intra prediction modes with a fixed number of weights needed per NxN block |
| 1.3 | Harmonization simplified linear interpolation intra prediction (LIP) with PDPC | JVET-M0252 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra Main 10 - Over VTM-3.0** | | | | | **Random Access Main 10 - Over VTM-3.0** | | | | |
| **Test #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 1.1.1 | -0.59% | -0.44% | -0.47% | 112% | 103% | -0.29% | -0.31% | -0.15% | 102% | 103% |
| 1.1.2 | -0.46% | -0.34% | -0.34% | 112% | 104% | -0.24% | -0.28% | -0.18% | 102% | 102% |
| 1.2.1 | -1.36% | -1.02% | -1.01% | 153% | 105% | -0.85% | -0.92% | -0.98% | 112% | 99% |
| 1.2.2 | -0.95% | -0.42% | -0.46% | 153% | 101% | -0.57% | -0.73% | -0.83% | 110% | 98% |
| 1.3 | -0.08% | -0.14% | -0.11% | 106% | 100% | -0.04% | 0.00% | -0.01% | 101% | 100% |

Regarding 1.1.x, it was commented that this does not really increase decoder complexity. Another participant commented that this has a difficult pipeline dependency. However, other difficult pipline dependencies are already in the VTM, and this is not increasing the difficulty of the worst case.

CE3.1: Related contributions

|  |  |  |
| --- | --- | --- |
| **Doc. #** | **Related test #** | **Title** |
| JVET-M0426 (HHI) | 1.1.2 | CE3-related: Improvement on the Intra Sub-Partitions Coding Mode |

CE3.1: Additional test results

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra Main10 - Over VTM-3.0** | | | | | **Random Access Main10 - Over VTM-3.0** | | | | |
| **Test#** | **Description** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 1.1.2.1 | Test 1.1.2 with 1-D transform and entropy coding for 4xN (N>4) blocks that cannot be vertically divided (JVET-M0102) | -0.52% | -0.40% | -0.42% | 112% | 104% | -0.25% | -0.25% | -0.16% | 102% | 102% |

It was noted that 1.1.x shows more gain on Class F (SCC content) than on other content, and Class F is not included in the average. A non-proponent participant focused on implementation issues indicated that they had analyzed it and found it acceptable for implementation.

Decision: Adopt CE3-1.1.1 proposal, text provided in revision of M0102.

This was further discussed in the plenary on Sunday 13 January, and it was agreed to revisit this topic since it has an aspect of reversal of decoding order which may cause it to be difficult to implement. This aspect was studied and agreed to be removed. See the notes of the two plenary discussions of this in section 11.1.

Regarding 1.2.1, this has (in the decoder perspective) a selection of a matrix of stored fixed values among a set of such matrices, followed by a matrix multiply applied to boundary sample values to generate the prediction signal in the frequency domain and then an inverse transform is applied to generate a spatial domain prediction, followed by an ordinary residual difference.

It was noted that this has a bit more gain on RA than is usual for intra coding efficiency proposals (0.85/1.36=0.625 versus the usual ~0.5).

This has some decoder runtime increase. For 1.2.1 there is an increase in computational operations.

It was commented that the need to include an inverse transform in the 1.2.1 variant is an additional functional block unlike anything typically done for intra.

The amount of stored coefficient data is another issue, especially for the 1.2.1 variant (~300 kbytes). The 1.2.2 variant omits the inverse transform and has a (simple 2-tap one-dimensional average) downsampling that reduces the size of the matrices (to about ~18 kbytes – a total of around 14,000 numbers of 10 bits each), with a corresponding (bilinear) upsampling in the decoder. The proponent pointed to CPR as an instance where added storage of a greater amount is needed (although, for screen content, that has quite high gain).

The encoding complexity is another significant concern; both proposed variants increase that by ~50%. Additional encoder-only variants are reported in M0043 with different trade-offs.

The proponent said the training set did not include the CTC test set.

Between 1/3 and 1/2 of the intra blocks were reportedly using this mode (which is a lot).

Further study was encouraged (not necessarily in a CE). Side activity was encouraged during the meeting to potentially come up with a plan for further study.

For 1.3, the proposal is to add an additional mode; the measured gain was quite small and the encoder runtime increased by about 6%, so no action was taken on this.

CE3.2 on ‘Cross-component prediction’

|  |  |  |
| --- | --- | --- |
| **Test #** | **Description** | **Doc. #** |
| 2.1 | CCLM + MDLM + MMLM | JVET-M0097 |
| 2.2 | CCLM + MDLM + MMLM + Above-MMLM + Left-MMLM | JVET-M0475 |
| 2.2.1 | Combination of 2.1 and 2.2 (\*) | JVET-M0098 |
| 2.3 | CCLM + MDLM + Adaptive multiple cross-component linear model | JVET-M0504 |
| 2.4 | Modified CCLM downsampling filter for “type-2” content (chroma sampling) | JVET-M0142 |
| 2.5.1 | CCLM + MDLM, using MaxMin method, and derived by using and | JVET-M0401 |
| 2.5.2 | CCLM + MDLM, using classification-based mean value method |
| 2.5.3 | CCLM + MDLM, using MaxMin method; using the first top row and the second left column |
| 2.5.4 | CCLM + MDLM, using classification-based mean value method; using the first top row and the second left column |
| 2.6.1 | CCLM accessing less neighbouring luma samples, interaction with other adopted coding tools: one row above and one column left luma samples are accessed | JVET-M0263 |
| 2.6.2 | 2.6.1 with three columns of left luma samples as in the anchor |

The VTM has 3 CCLM modes (CCLM, CCLM-above, and CCLM-left). The selection between these modes is signalled, but the model parameters are not. The tests in the CE are to improve coding efficiency by adding more models.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Test 2.1 | Test 2.2 | Combination test 2.2.1 |
| Signalling | Adds MMLM modes in LM symbol list | Uses flag and index to indicate MMLM mode | Same as 2.2 |
| Number of lines used for model derivation | Same as CCLM/MDLM  (i.e., Y: 2 lines above, 3 lines left, C: 1 line above and left) | (Y: 4 lines above, 5 lines left, C: 2 lines above and left) | Same as CCLM/MDLM  (i.e., Y: 2 lines above, 3 lines left, C: 1 line above and left) |

* 2.1 uses 3 columns to the left and 2 lines above (except at the CTU boundary)
* 2.2 uses 5 columns to the left and 4 lines above (except at the CTU boundary)
* Between 2.1, 2.2, and 2.2.1, it was suggested to focus on the combination test 2.2.1, for using fewer lines and cleaner signalling

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra Main10 - Over VTM-3.0** | | | | | **Random Access Main10 - Over VTM-3.0** | | | | |
| **Test #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 2.1 | -0.25% | -1.71% | -2.19% | 100% | 100% | -0.12% | -1.36% | -1.70% | 99% | 99% |
| 2.2 | -0.29% | -1.94% | -2.51% | 100% | 100% | -0.15% | -1.70% | -1.99% | 101% | 100% |
| 2.2.1 | -0.27% | -1.71% | -2.26% | 99% | 99% | -0.13% | -1.30% | -1.73% | 99% | 98% |
| 2.3 | -0.10% | -0.86% | -0.88% | 102% | 100% | -0.03% | -0.62% | -0.66% | 100% | 100% |
| 2.4 | See below (\*) |  |  |  |  |  |  |  |  |  |
| 2.5.1 | -0.09% | -0.44% | -0.47% | 100% | 99% | -0.08% | -0.31% | -0.39% | 100% | 99% |
| 2.5.2 | -0.18% | -0.88% | -0.90% | 100% | 99% | -0.11% | -0.74% | -0.84% | 100% | 99% |
| 2.5.3 | 0.05% | 0.45% | 0.48% | 100% | 100% | 0.02% | 0.51% | 0.51% | 100% | 99% |
| 2.5.4 | -0.14% | -0.51% | -0.51% | 100% | 101% | -0.09% | -0.41% | -0.46% | 100% | 99% |
| 2.6.1 | 0.09% | 0.71% | 0.79% | 99% | 97% | 0.06% | 0.88% | 0.95% | 100% | 99% |
| 2.6.2 | 0.03% | 0.16% | 0.21% | 100% | 97% | 0.00% | 0.35% | 0.35% | 100% | 99% |

(\*) Summary of test 2.4:

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra – Over VTM3.0 WCG\_EXT=1** | | | | | | | | | |
| **Test #** | **Description** | **DE100** | **PSNRL100** | **wPsnrY** | **wPsnrU** | **wPsnrV** | **PsnrY** | **PsnrU** | **PsnrV** | **EncT** | **DecT** |
| 2.4.a | LM determination: 3-tap filter; prediction: 3-tap filter | -2.5% | -0.2% | -0.2% | -4.2% | -8.6% | -0.2% | -3.4% | -6.7% | 101% | 101% |
| 2.4.b | LM determination: 3-tap filter; prediction: 5-tap filter | -2.2% | -0.2% | -0.2% | -4.7% | -8.6% | -0.2% | -4.0% | -6.8% | 101% | 102% |
| 2.4.c | LM determination: 5-tap filter; prediction: 5-tap filter | -2.6% | -0.3% | -0.2% | -5.5% | -9.6% | -0.2% | -4.6% | -7.6% | 99% | 101% |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Random Access – Over VTM3.0 WCG\_EXT=1** | | | | | | | | | |
| **Test #** | **Description** | **DE100** | **PSNRL100** | **wPsnrY** | **wPsnrU** | **wPsnrV** | **PsnrY** | **PsnrU** | **PsnrV** | **EncT** | **DecT** |
| 2.4.a | LM determination: 3-tap filter; prediction: 3-tap filter | -1.9% | -0.2% | -0.1% | -4.2% | -5.8% | -0.1% | -3.3% | -4.5% | 101% | 99% |
| 2.4.b | LM determination: 3-tap filter; prediction: 5-tap filter | -1.7% | -0.1% | -0.1% | -4.7% | -6.0% | -0.1% | -3.7% | -4.6% | 101% | 100% |
| 2.4.c | LM determination: 5-tap filter; prediction: 5-tap filter | -2.1% | -0.2% | -0.2% | -5.1% | -6.6% | -0.2% | -4.1% | -5.1% | 102% | 101% |

Some comments:

* Chroma gain tends to roughly translate to luma gain at about a 1:10 ratio
* Chroma gain in the CTC is often dominated by one particular test sequence: CampFire
* The MDLM scheme adopted at the previous meeting provided about 2.7% chroma gain
* The proposed MMLM schemes double the number of models derived and used.

Notes of the previous meeting: “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 [for AI; RA: 0.1% luma, approx. 2.0% for chroma – for 5.2.3.4 scheme]. 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.”

In response to the above notes:

* The gain is somewhat less now: AI: -0.27%, -1.71%, -2.26%, RA: -0.13%, -1.30%, -1.73%
* The complexity concern (e.g., latency added by determining the threshold and applying the classification step; although the cross-component prediction may not be in a critical-latency path) remains valid.
* It was remarked that even with the current scheme, the complexity is a problem, esp. for small blocks (2x2 chroma).

Due to complexity concerns, no action was taken on 2.1/2.2/2.2.1. This will be further discussed in the CE-related BoG to clarify the concerns and recommend what to further study.

2.3 has an adaptive number of models, sometimes more than two per component, and showed less gain, so no action was taken on that.

Regarding 2.4.x, the current scheme is optimized for type 0 chroma (the usual chroma per Rec. 709); 2.4 compensates for co-sited chroma (type 2 per BT.2100). The 2.4 test was done only on the PQ sequences. A decoder might need to support two chroma types, with encoder high-level selection of which to apply.

Testing was not done to determine the potential penalty of running the type 2 optimized scheme on type 0 content. Test results for this were requested.

A participant remarked that he had done some testing on self-generated content that used type 1 (centered both horizontally and vertically) and found not so much (~1-2%) benefit for customizing for that chroma siting. Here the experiments show a much more substantial gain for optimization to type 2.

It was commented that proper chroma alignment may be more visually important than what shows up in objective metrics.

The kernel of the 2.4.c 5-tap filter (except at CTU boundaries, where only one line above is used) is:

0 1 0

1 4 1

0 1 0

Decision: Adopt 2.4.c with a high-level flag to switch between two chroma format type optimizations.

Test results for applying the type 2 scheme to type 0 content. were discussed in a plenary. See notes in section 11.1 about that.

For 2.5.x, there was a focus on the first two variants. These are adding some additional complexity. The gain seemed insuffient to justify changing the current scheme.

2.6.1 reduces the number of neighbour lines used to compute the model parameters to 1 (where the current VTM scheme uses 3 columns to the left and 2 rows above when within the current CTU). 2.6.2 uses 3 columns to the left but only one row above. These would make the processing consistent whether within a CTU or at the boundary.

But it was commented that adoption of the 2.6.1 or 2.6.2 scheme would not be reducing the line buffering needed in a decoder, since it does not apply for the other chroma type. It was also commented that the question of 1 or 2 lines had been discussed at the previous meeting and the 2 line scheme was considered not a problem. So no action was taken on the 2.6.x proposals.

CE3.3 on ‘Intra mode coding’

|  |  |  |
| --- | --- | --- |
| **Test #** | **Description** | **Doc. #** |
| 3.1.1 | Decoder-side intra mode derivation | JVET-M0094 |
| 3.1.2 | Decoder-side intra mode selection with predictor coding (3 candidates) |
| 3.1.3 | Decoder-side intra mode derivation with extended gradient filtering for directly neighboring pixels |
| 3.1.4 | Decoder-side intra mode derivation restricted for blocks with a number of samples <= 128 |
| 3.2 | 6 MPMs and 32 remaining modes (5-bit FLC) | JVET-M0495 |
| 3.3.1 | Simplified MDMS with 5 chroma intra modes (2-point DM, 5 non-LM) | JVET-M0218 |
| 3.3.2 | Simplified MDMS with the reduced chroma intra modes (2-point DM, 3 non-LM) |
| 3.4.1 | Simplified MDMS by reducing the number of operations (2-point DM, 5 non-LM) | JVET-M0503 |
| 3.4.2 | Simplified MDMS by reducing the number of candidates (2-point DM, 3 non-LM) |
| 3.5 | Simplified MDMS with one DM (1-point DM, 5 non-LM) | JVET-M0203 |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test #** | **All Intra Main10 - Over VTM-3.0** | | | | | **Random Access Main10 - Over VTM-3.0** | | | | |
| **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 3.1.1 | -0.11% | -0.09% | -0.08% | 122% | 103% | -0.07% | -0.06% | -0.07% | 104% | 101% |
| 3.1.2 | -0.01% | -0.05% | -0.02% | 122% | 102% | 0.01% | 0.06% | 0.04% | 103% | 100% |
| 3.1.3 | -0.12% | -0.04% | -0.05% | 124% | 104% | -0.05% | -0.01% | 0.03% | 103% | 101% |
| 3.1.4 | -0.09% | -0.09% | -0.06% | 113% | 103% | -0.05% | 0.10% | 0.01% | 100% | 100% |
| 3.2 | -0.03% | -0.04% | -0.05% | 97% | 100% | 0.02% | 0.14% | 0.13% | 99% | 99% |
| 3.3.1 | -0.03% | -0.88% | -0.86% | 100% | 100% | -0.01% | -0.46% | -0.50% | 100% | 100% |
| 3.3.2 | -0.02% | -0.29% | -0.20% | 97% | 100% | 0.00% | -0.12% | -0.05% | 99% | 100% |
| 3.4.1 | -0.02% | -0.96% | -1.03% | 101% | 99% | 0.04% | -0.98% | -1.04% | 100% | 100% |
| 3.4.2 | 0.03% | -0.34% | -0.32% | 97% | 100% | 0.10% | -0.86% | -0.92% | 99% | 100% |
| 3.5 | -0.01% | -0.61% | -0.64% | 100% | 100% | 0.06% | -0.68% | -0.76% | 100% | 101% |

CE3.3: Additional test results

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test #** | **Description** | **All Intra Main10 - Over VTM-3.0** | | | | | **Random Access Main10 - Over VTM-3.0** | | | | |
| **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 3.5.1 | Simplified MDMS with one DM by using aligned chroma coding of VVC-3.0 (1-point DM, 4 non-LM) | -0.02% | -0.58% | -0.61% | 100% | 100% | -0.02% | -0.37% | -0.39% | 100% | 100% |

For 3.1.x, the proposal is to add another mode in which the intra prediction mode is inferred by decoder processing rather than signalled. This adds encoder (and some decoder) complexity, but the test results do not show much benefit from this, so no action was taken on this.

For 3.2, the proposal is to restrict the number of selectable intra prediction modes to 32 of the 67. Some gain is observed, but only a small amount, and it was commented that the restriction of what modes an encoder would be allowed to select would restrict encoder freedom on how to make its mode decisions (not allowing an encoder to choose a mode until after it is able to determine which 32 of the 67 are allowed for selection), so no action was taken on this.

3.3.1, 3.3.2, 3.4.1, 3.4.2, and 3.5 are regarding chroma mode coding, which is dependent on luma mode. 3.3.1 and 3.4.1 would increase decoder complexity. One key aspect is how many luma points are considered for deriving the chroma mode candidates (1 or 2). Another key aspect is how many chroma mode candidates there are (3 or 5).

Schemes 3.3.2 and 3.4.2 reduce the number of candidates from 5 to 3. As tested, this reduced encoding time since the encoder checked fewer modes, although the decoder complexity is higher than for the current scheme (because it uses a 2-point check for direct mode selection). It was commented that the DC, planar, horizontal and vertical modes are especially important for some encoder implementations. If these are not always selectable, it would force a dependency between luma and chroma for encoding decisions. These two schemes did not provide much coding gain, although in the way they were tested, they reduced encoding time. The lack of significant coding gain, together with that dependency, did not appear to justify action on those.

Results for an additional scheme called 3.5.1 (proposed in JVET-M0203) were included in the CE report. This was a late addition that was not in the CE plan, so it was considered a non-CE proposal.

3.3.1 and 3.4.1 check two luma locations, whereas the VTM checks only 1 (the central position of the luma block). The VTM sends a flag on whether to use that mode; if not, it sends a CCLM mode flag; if not, it sends 2 bypass-coded bins to select between four modes. If the luma mode was not DC, planar, horizontal or vertical, then those are the four modes; otherwise the luma mode is replaced with the vertical diagonal mode to determine the four modes.

3.3.1 and 3.4.1 check two luma locations and perform some comparison flowchart operations to determine what is the primary selectable mode and what are the other four modes. The DC and planar modes are always among the 5 selectable modes. It was noted that this forces a dependency between the luma and chroma mode decisions unless the encoder only used DC and planar modes for chroma.

The possibility of supporting both the current scheme and the alternative was discussed. The gain seemed insufficient to want to need two different ways to be supported in the decoder.

3.5 checks one luma location (same as VTM); if the luma mode is DC or planar and the block shape is vertical, then instead of the vertical diagonal mode being considered special, the horizontal diagonal mode is considered special; if the luma mode is angular, the other selectable modes are determined by a flowchart (but the horizontal and vertical modes are not always available). This has basically the same forced cross-component dependency as 3.3.1 and 3.4.1.

Since the gain is relatively small and the 3.3.1, 3.3.2, 3.4.1, 3.4.2, and 3.5 proposals introduce an undesirable cross-component dependency for encoders, no action was taken on on these.

[JVET-M0043](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4843) CE3: Affine linear weighted intra prediction (test 1.2.1, test 1.2.2) [J. Pfaff, B. Stallenberger, M. Schäfer, P. Merkle, P. Helle, R. Rischke, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

[JVET-M0094](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4897) CE3: Decoder-side Intra Mode Derivation (tests 3.1.1, 3.1.2, 3.1.3 and 3.1.4) [E. Mora, A. Nasrallah, M. Abdoli, M. Raulet (ATEME)]

[JVET-M0097](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4902) CE3: On MMLM (Test 2.1) [A. K. Ramasubramonian, G. Van der Auwera, T. Hsieh, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-M0098](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4903) CE3: Joint test on MMLM (Test 2.2.1) [A. K. Ramasubramonian, G. Van der Auwera, T. Hsieh, V. Seregin, M. Karczewicz (Qualcomm), H.-J. Jhu, Y.-J. Chang (Foxconn)]

[JVET-M0102](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4907) CE3: Intra Sub-Partitions Coding Mode (Tests 1.1.1 and 1.1.2) [S. De-Luxán-Hernández, V. George, J. Ma, T. Nguyen, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

[JVET-M0142](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4949) CE3: Modified CCLM downsampling filter for “type 2” content (Test 2.4) [P. Hanhart, Y. He (InterDigital)]

[JVET-M0203](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5010) CE3: DM-based chroma intra prediction mode (Test 3.5) [N. Choi, M. W. Park, K. Choi (Samsung)]

[JVET-M0218](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5025) CE3: Simplified MDMS (test 3.3.1 and test 3.3.2) [J. Choi, J. Heo, S. Yoo, L. Li, J. Choi, J. Lim, S. Kim (LGE)]

[JVET-M0252](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5059) CE3-1.3: Harmonization of Linear interpolation intra prediction (LIP) with Multiple reference line prediction (MRL) [J. Heo, J. Choi, J. Choi, S. Yoo, L. Li, J. Lim (LGE)]

[JVET-M0263](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5070) CE3: CCLM prediction with single-line neighbouring luma samples (Test 2.6.1 and Test 2.6.2) [K. Zhang, L. Zhang, H. Liu, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-M0401](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5206) CE3: Classification-based mean value for CCLM coefficients derivation (tests 2.5.1-2.5.4) [X. Ma, A. Filippov, V. Rufitskiy, H. Yang, J. Chen (Huawei)]

[JVET-M0475](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5285) CE3: Multiple neighbour LM (Test 3.2.2) [[H.-J. Jhu](mailto:HongJheng@fginnov.com), Y.-J. Chang (Foxconn)]

[JVET-M0495](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5305) CE3: Intra mode coding (Test 3.2) [L. Zhao, X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-M0503](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5313) CE3: Chroma intra prediction simplification (Test 3.4.1 and 3.4.2) [C.-H. Yau, C.-C. Lin, C.-L. Lin (ITRI)]

[JVET-M0504](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5314) CE3: adaptive multiple cross-component linear model (Test 3.2.3) [S.-P. Wang, C.-H. Yau, C.-C. Lin, C.-L. Lin (ITRI)]

## CE4: Inter prediction and motion vector coding (18)

Contributions in this category were discussed Thursday 10 Jan. 1120–1340 and 1500-2000 (Track B chaired by JRO).

[JVET-M0024](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5408) 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 5 categories,

1. Merge mode simplification
2. Merge mode enhancement
3. Parallel processing for merge mode
4. Motion vector coding
5. Motion compensation constraints for complexity reduction

All techniques are implemented on top of and test against VTM 3.0. Simulation results and crosschecking reports of each test specified in this document are provided.

CE4.1: Merge mode simplification

|  |  |  |
| --- | --- | --- |
| **Test#** | **Source** | **Description** |
| 4.1.1.a | JVET-M0124 | Reduce HMVP candidates from 5 to 5 - NST  (NST: number of spatial/temporal candidates) |
| 4.1.1.b | JVET-M0124 | Reduce HMVP candidates from 5 to 6 - NST |
| 4.1.1.c | JVET-M0124 | Apply 4.1.1.a when NST >=3 |
| 4.1.1.d | JVET-M0124 | Apply 4.1.1.b when NST >=3 |
| 4.1.2.a | JVET-M0126 | 1) HMVP buffer size is increased from 6 to 10, with no pruning to update the buffer.  2) One out of every 3 is picked to add in the merge list. 4 HMVP candidates at most  3) Pairwise candidates are generated not using HMVP candidates.  4) First 3 HMVP candidates are pruned to the left and above spatial candidates |
| 4.1.2.b | JVET-M0126 | 4.1.2.a 1) 2) 3) + 4) First 2 HMVP candidates are pruned to the left and above spatial candidates |
| 4.1.5.a | JVET-M0281 | Motion vector pruning: rounding before any MV pruning |
| 4.1.5.b | JVET-M0281 | In merge apply some pruning on combined HEVC candidates, and/or pairwise averaged candidates |
| 4.1.5.c | JVET-M0281 | 4.1.5.a + 4.1.5.b |

Regarding JVET-M0126, only aspects 1) and 2) were in the original proposal (JVET-L0401), whereas aspects 3) and 4) were included in the first release of the software. It is suggested that the proponents also provide separate results which show the benefit of combination 1/2, as well as 3-only and 4-only separately.

Results were made available in JVET-M0126v8. Based on this analysis, it was found that only the method 4.1.2.4 (First 2 HMVP candidates are pruned to the left and above spatial candidates) is relevant. This would be competing with 4.1.1.a. Both methods have significant reduction in number of pruning process compared to the current design, where 4.1.2.4 has even slightly less complexity, and loss of compression seems to be more homogeneous over RA and LB (approx. 0.04% luma), and over different sequences.

Decision: Adopt JVET-M0126 version 4.1.2.4 (text is available, but needs to be reduced reflect that only this aspect is changed.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.1.1.a | 0.00% | 0.07% | 0.02% | 100% | 100% | 0.07% | 0.14% | 0.22% | 101% | 99% |
| 4.1.1.b | 0.00% | 0.02% | 0.06% | 100% | 101% | 0.02% | 0.01% | 0.00% | 101% | 100% |
| 4.1.1.c | -0.04% | 0.00% | -0.01% | 100% | 100% | 0.05% | 0.06% | 0.00% | 101% | 99% |
| 4.1.1.d | -0.02% | 0.00% | 0.01% | 100% | 99% | 0.03% | -0.04% | -0.02% | 100% | 100% |
| 4.1.2.a | 0.03% | 0.06% | 0.03% | 100% | 100% | 0.08% | 0.07% | 0.13% | 100% | 99% |
| 4.1.2.b | 0.03% | 0.02% | 0.04% | 100% | 100% | 0.08% | -0.03% | 0.08% | 99% | 98% |
| 4.1.5.a | 0.00% | -0.01% | 0.00% | 100% | 100% | -0.01% | -0.04% | -0.01% | 100% | 100% |
| 4.1.5.b | -0.02% | 0.00% | 0.00% | 100% | 100% | 0.02% | 0.09% | -0.09% | 99% | 100% |
| 4.1.5.c | -0.02% | -0.03% | -0.01% | 100% | 100% | -0.02% | 0.06% | 0.07% | 99% | 100% |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Test#** | **Difference in the number of candidate comparison (+/- xx)** | **Max number of pruning stages** | **Others** | **RA** | **LB** |
| 4.1.1.a | -4 | unchanged |  | 0.00% | 0.07% |
| 4.1.1.b | -2 | unchanged |  | 0.00% | 0.02% |
| 4.1.1.c | -3 | unchanged |  | -0.04% | 0.05% |
| 4.1.1.d | -2 | unchanged |  | -0.02% | 0.03% |
| 4.1.2.a | -8 | -2 | HMVP table = 10 | 0.03% | 0.08% |
| 4.1.2.b | -10 | -3 | HMVP table=10, runtime saving of HMVP functions is 59%(RA), 62%(LB) | 0.03% | 0.08% |
| 4.1.5.a | +0 | +0 |  | 0.00% | -0.01% |
| 4.1.5.b | +6 | +1 | Discard pairwise calculation | -0.02% | 0.02% |
| 4.1.5.c | +6 | +1 | Discard pairwise calculation | -0.02% | -0.02% |

The table above should be updated to get better understanding of the properties. 4.1.1 and 4.1.2 are modifying HMVP. In particular, the number of maximum pruning operations and comparison operations necessary during table construction and during merge should be listed separately. Number of cycles should also be calculated rather than number of pruning stages. It is reported that 4.1.2 is not doing any pruning during table construction (using FIFO list, but with extended length from 5 to 10) and also reduces the number of pruning operations in merge list construction. 4.1.1. is keeping the HMVP list construction unchanged, but reduces the pruning operations in merge list construction.

More analysis became available (see under the discussion of the adoption of M0126 above).

4.1.5a is performing rounding of candidates before the AMVP list construction. Currently, it is done before AMVP list construction for AMVP 1 pel and 4 pel accuracy, and from 1/16 pel to 1/4 pel after merge list construction for AMVP 1/4 pel accuracy. This makes the design more consistent. It is noted that alternatively consistency could be achieved by doing rounding after merge list construction for 1 pel and 4 pel accuracy, however this was reported to have been tried and gave loss, as candidates which were identical after rounding would have been different before rounding. Some support and no objection was raised on this approach. Decision: Adopt JVET-M0281 (subtest 4.1.5a)

4.1.5b adds another pruning stage in merge list construction for 0.02% coding gain. (before VTM3, there was higher gain on such an approach)

CE4.2: Merge mode enhancement

|  |  |  |
| --- | --- | --- |
| **Test#** | **Source** | **Description** |
| 4.2.1.a | JVET-M0059 | +One non-scaling STMVP: Averaging the first two spatial candidates and TMVP |
| 4.2.2.a | JVET-M0106 | +One non-scaling STMVP: STMVP using a single adjacent above candidate, a single adjacent left candidate and a TMVP candidate. The single adjacent candidate is the first valid one checked at three potential positions. |
| 4.2.2.b | JVET-M0106 | 4.2.2.a with merge list size = 8 |
| 4.2.2.c | JVET-M0106 | 4.2.2.a + One more STMVP candidate (two spatial average) + Remove pair-wise candidate |
| 4.2.2.d | JVET-M0106 | 4.2.2.c with merge list size = 8 |
| 4.2.3.a | JVET-M0221 | +One non-scaling STMVP: Averaging the left spatial, above spatial and TMVP |
| 4.2.4.a | JVET-M0404 | +One non-scaling STMVP: Averaging the first two HMVP candidates and TMVP |
| 4.2.5.a | JVET-M0291 | MMVD modifications: 1) increase base candidates from 2 to 3; 2) Decrease distance index from 8 to 4. |
| 4.2.5.b | JVET-M0291 | MMVD modifications: 1) increase directions from 4 to 8; 2) Decrease distance index from 8 to 4. |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.2.1.a | -0.09% | -0.04% | -0.06% | 100% | 100% | 0.00% | 0.00% | 0.00% | 100% | 102% |
| 4.2.2.a | -0.11% | -0.03% | 0.00% | 101% | 99% | 0.00% | -0.12% | 0.02% | 107% | 110% |
| 4.2.2.b | -0.17% | -0.10% | -0.09% | 101% | 100% | -0.06% | -0.14% | -0.25% | 107% | 110% |
| 4.2.2.c | -0.15% | -0.10% | -0.13% | 100% | 100% | 0.00% | -0.18% | 0.01% | 107% | 110% |
| 4.2.2.d | -0.23% | -0.15% | -0.13% | 101% | 100% | -0.06% | -0.16% | -0.11% | 107% | 111% |
| 4.2.3.a | 0.00% | 0.00% | -0.01% | 101% | 101% | 0.11% | 0.18% | 0.29% | 100% | 101% |
| 4.2.4.a | -0.03% | 0.05% | 0.00% | 108% | 106% | 0.16% | 0.28% | 0.13% | 110% | 109% |
| 4.2.5.a | 0.07% | 0.17% | 0.14% | 100% | 95% | 0.03% | 0.13% | 0.24% | 100% | 97% |
| 4.2.5.b | 0.02% | 0.17% | 0.14% | 100% | 97% | -0.07% | 0.10% | 0.10% | 100% | 94% |

Current VTM3: Merge list size 6, Max number of potential candidates 18, Max number of candidate comparisons 15, Max number of pruning stages 8-9(?)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test#** | **Merge list size** | **Max number of potential candidates** | **Max number of candidate comparison** | **Max number of pruning stages** | **Max number of MV scaling** | **Others** | **RA** | **LB** |
| 4.2.1.a | 6 | +1 | 0 | 0 | 0 |  | -0.09% | 0.00% |
| 4.2.2.a | 6 | +1 | +4 | +1 | +0 |  | -0.11% | 0.00% |
| 4.2.2.b | 8 | +1 | +4 | +1 | +0 |  | -0.17% | -0.06% |
| 4.2.2.c | 6 | +2 | +9 | +2 | +0 |  | -0.15% | 0.00% |
| 4.2.2.d | 8 | +2 | +9 | +2 | +0 |  | -0.23% | -0.06% |
| 4.2.3.a | 6 |  |  |  |  |  | 0.00% | 0.11% |
| 4.2.4.a | 6 |  |  |  |  |  | -0.03% | 0.16% |
| 4.2.5.a | 6 |  |  |  |  |  | 0.07% | 0.03% |
| 4.2.5.b | 6 |  |  |  |  |  | 0.02% | -0.07% |

4.2.1 through 4.2.4 relate to STMVP, 4.2.5 relates to MMVD. All proposals target providing compression gain by doing some additional processing. 4.2.3 and 4.2.4 have not provided complexity data so far (by 2nd day of meeting), but also do not seem to provide advantage in compression.

From the results above, better results are obviously possible with more complexity.

It was agreed that the merge list size should not be increased. Therefore, only 4.2.1a, 4.2.2a/c are reasonable proposals. Among these, 4.2.1a has the best tradeoff performance/complexity. It is however mentioned that the method was disabled for LB test, because it would have provided small loss (due to missing scaling). It would be an undesirable design to change the list of candidates depending on the frame dependencies.

In 4.2.1a, the additional STMVP candidate is put into the list at the position before the B2 (and therefore also before pairwise and HMVP candidates). Furthermore, there are some additional checks in the algorithm that are not reflected in the table above.

After all, none of the proposals provides sufficient benefit to take action.

4.2.5 should better be considered in context of CE4.4 (MV coding)

CE4.3: Parallel processing for merge mode

|  |  |  |
| --- | --- | --- |
| **Test#** | **Source** | **Description** |
| 4.3.1.a | JVET-M0170 | Share merge list for translational merge and sub-CU merge with fixed threshold = 32 |
| 4.3.1.b | JVET-M0170 | Share merge list for translational merge and sub-CU merge with fixed threshold = 64 |
| 4.3.1.c | JVET-M0170 | Share merge list for translational merge and sub-CU merge with fixed threshold = 128 |
| 4.3.1.d | JVET-M0170 | Share merge list for translational merge and sub-CU merge with fixed threshold = 256 |
| 4.3.1.e | JVET-M0170 | Share merge list for translational merge and sub-CU merge with fixed threshold = 512 |
| 4.3.2.a | JVET-M0289 | S1: A neighbor coding block is marked as unavailable if its bottom right coordinate falls in the extended merge estimation region of the current block.  Fixed square MER = 8x8 |
| 4.3.2.b | JVET-M0289 | S1. Fixed square MER = 16x16 |
| 4.3.2.c | JVET-M0289 | S1. Fixed square MER = 32x32 |
| 4.3.2.d | JVET-M0289 | S1. Fixed square MER = 64x64 |
| 4.3.2.e | JVET-M0289 | S2: A neighbor coding block is marked as unavailable if its bottom right coordinate falls in the estimation region of the current block and the QT depth of the current block is equal to or greater than the value of CTU size divided by MER size.  Fixed square MER = 8x8 |
| 4.3.2.f | JVET-M0289 | S2. Fixed square MER = 16x16 |
| 4.3.2.g | JVET-M0289 | S2. Fixed square MER = 32x32 |
| 4.3.2.h | JVET-M0289 | S2. Fixed square MER = 64x64 |
| 4.3.2.i | JVET-M0289 | S3: A neighbor coding block is marked as unavailable if its bottom right coordinate falls in the rectangular merge estimation region of the current block.  Rectangular MER = 32 |
| 4.3.2.j | JVET-M0289 | S3: Rectangular MER = 64 |
| 4.3.2.k | JVET-M0289 | S3: Rectangular MER = 128 |
| 4.3.2.l | JVET-M0289 | S3: Rectangular MER = 256 |

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Thrs/MER** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.3.1.a | 32 | 0.00% | 0.00% | 0.00% | 101% | 102% | 0.02% | -0.05% | -0.04% | 101% | 102% |
| 4.3.1.b | 64 | 0.04% | 0.02% | 0.05% | 101% | 104% | 0.08% | -0.04% | 0.15% | 101% | 102% |
| 4.3.1.c | 128 | 0.12% | 0.18% | 0.16% | 101% | 102% | 0.14% | 0.22% | 0.28% | 102% | 102% |
| 4.3.1.d | 256 | 0.44% | 0.52% | 0.66% | 102% | 103% | 0.63% | 0.68% | 0.69% | 103% | 102% |
| 4.3.1.e | 512 | 0.68% | 0.85% | 0.92% | 102% | 102% | 0.93% | 0.86% | 1.09% | 103% | 101% |
| 4.3.2.a | 8x8 (S1) | 0.16% | 0.27% | 0.25% | 100% | 101% | 0.14% | 0.13% | 0.36% | 100% | 101% |
| 4.3.2.b | 16x16 (S1) | 0.55% | 0.67% | 0.78% | 101% | 101% | 0.56% | 0.66% | 0.70% | 101% | 102% |
| 4.3.2.c | 32x32 (S1) | 1.41% | 1.64% | 1.69% | 104% | 100% | 1.41% | 1.38% | 1.54% | 103% | 100% |
| 4.3.2.d | 64x64 (S1) | 2.62% | 2.72% | 2.97% | 106% | 100% | 2.51% | 2.56% | 2.61% | 104% | 100% |
| 4.3.2.e | 8x8 (S2) | 0.02% | 0.01% | 0.03% | 99% | 100% | 0.01% | 0.08% | 0.04% | 100% | 101% |
| 4.3.2.f | 16x16 (S2) | 0.16% | 0.24% | 0.26% | 100% | 99% | 0.16% | 0.11% | 0.18% | 101% | 101% |
| 4.3.2.g | 32x32 (S2) | 1.09% | 1.27% | 1.44% | 102% | 99% | 1.13% | 1.20% | 1.20% | 102% | 100% |
| 4.3.2.h | 64x64 (S2) | 2.59% | 2.66% | 2.92% | 105% | 98% | 2.44% | 2.45% | 2.51% | 103% | 96% |
| 4.3.2.i | 32 (S3) | 0.00% | 0.07% | 0.04% | 100% | 101% | 0.00% | 0.04% | 0.04% | 101% | 104% |
| 4.3.2.j | 64 (S3) | 0.03% | 0.06% | 0.06% | 101% | 102% | 0.01% | 0.04% | -0.17% | 101% | 105% |
| 4.3.2.k | 128 (S3) | 0.15% | 0.20% | 0.27% | 101% | 102% | 0.15% | 0.22% | 0.06% | 102% | 104% |
| 4.3.2.l | 256 (S3) | 0.35% | 0.47% | 0.55% | 102% | 101% | 0.37% | 0.31% | 0.50% | 102% | 104% |

Similar concepts (shared merge of JVET-M0170, parallel merge of JVET-M0289) have been used in HEVC, where parallel is regarded mostly beneficial for parallel processing at the encoder, whereas shared merge could also have some benefit for the decoder, as it is not necessary to generate merge lists separately for very small blocks (however only if the sharing would be made mandatory, which is not the case in HEVC). However, due to the fact that VVC has more irregular (non-square) block structures, consistent definition of regions which use shared merge / parallel merge becomes more difficult. For example, if the regions are square, it may happen that a rectangular block is only partially included. 4.3.1 and 4.3.2 S3 try to solve that by introducing non-square regions below some parent node of the tree.

Both approaches require normative changes. Making the decoder more complex for the benefit of a parallel encoder may be not as desirable as it was in HEVC, in particular as it is more irregular due to non-square blocks. Reducing decoder complexity by sharing merge lists between very small blocks (e.g. two adjacent 4x4 blocks use same merge seems relative simple to define and would be beneficial if it is normative. Results from test 4.3.1a above are from a version called “type1” in JVET-M0170, whereas “type2” (that is also described in JVET-M0170) with threshold 32 would be the desirable solution. The type2 is understood in a way that if after a split any block is smaller than the threshold, all blocks of that split share the same merge list (e.g. 16x4 split ternary or 8x8 with quad split). This needs to be mandatory. Reportedly, this comes with no loss for luma, and some negligible loss (0.03/0.06%) for chroma. This was being cross-checked in JVET-M0584 (“supplementary test D1”) which was not finished yet.

This was revisited after the cross-check was finished. Cross-checkers had been asked to investigate the code and associated specification. The specification text should be simplified such that the threshold is not signalled, but always used as 32. X.Li is also asked to inspect the code and text.

It was later confirmed (Tue 15 Jan afternoon) by the cross-checkers and X. Li that everything is consistent as requested above. Text is available in v4 of M0170.

Decision: Adopt JVET-M0170 (type 2, draft text “…type2sharing” of Jan. 12)

Further study on the aspects that simplify encoder, in particular also by investigating the potential of non-normative solutions. It is mentioned that by the time when parallel merge was introduced in HEVC, a corresponding non-normative solution would have lost about 2% in compression performance.

CE4.4: Motion vector coding

|  |  |  |
| --- | --- | --- |
| **Test#** | **Source** | **Description** |
| 4.4.1.a | JVET-M0403 | MVD is not signaled as x/y components but as layer and index: Two layer-groups. |
| 4.4.1.b | JVET-M0403 | MVD is not signaled as x/y components but as layer and index: Four layer-groups. |
| 4.4.3 | JVET-M0481 | Symmetrical MVD mode: BiDirPredFlag, RefIdxSymL0 and RefIdxSymL1 are derived at slice level; Only mvp\_l0\_flag, mvp\_l1\_flag and MVD0 are explicitly signaled; MVD1=-MVD0. |
| 4.4.4.a | JVET-M0060 | Diagonal direction candidate for MMVD: Increase MMVD directions from 4 to 8. |
| 4.4.4.b | JVET-M0060 | Multiple distance lists for MMVD: Two distance lists, each of which has 4 entries. |
| 4.4.4.c | JVET-M0060 | 4.4.4.a + 4.4.4.b |
| 4.4.4.d | JVET-M0060 | 4.4.4.c+ full-pel position for large range: MV is rounded to integer if the second list is selected and distance index > 1 |
| 4.4.4.e | JVET-M0061 | Combination of 4.4.4.a and 4.4.5.c |
| 4.4.5.a | JVET-M0312 | MMVD with adaptive distance table based on occurrences: The distance table is updated at slice level according to a gain-comparison algorithm. |
| 4.4.5.b | JVET-M0312 | MMVD with adaptive distance table based on picture resolution: A special distance table is used on 4K-sequences. |
| 4.4.5.c | JVET-M0312 | 4.4.5.a + 4.4.5.b |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.4.1.a | 0.01% | 0.02% | 0.02% | 96% | 96% | 0.03% | -0.09% | -0.11% | 97% | 92% |
| 4.4.1.b | 0.00% | 0.04% | 0.02% | 96% | 96% | -0.01% | 0.01% | -0.02% | 97% | 92% |
| 4.4.3 | -0.16% | -0.12% | -0.16% | 105% | 100% | 0.00% | 0.00% | 0.00% | 100% | 100% |
| 4.4.4.a | -0.13% | -0.07% | -0.08% | 106% | 100% | -0.05% | 0.03% | 0.00% | 104% | 100% |
| 4.4.4.b | -0.05% | 0.03% | 0.01% | 102% | 100% | 0.09% | 0.09% | 0.11% | 101% | 100% |
| 4.4.4.c | -0.28% | -0.16% | -0.19% | 106% | 100% | 0.01% | 0.14% | 0.25% | 104% | 100% |
| 4.4.4.d | -0.28% | -0.17% | -0.20% | 106% | 100% | 0.00% | 0.28% | 0.07% | 103% | 100% |
| 4.4.4.e | -0.38% | -0.39% | -0.48% | 101% | 100% | -0.15% | -0.11% | -0.01% | 102% | 100% |
| 4.4.5.a | -0.22% | -0.33% | -0.35% | 103% | 98% | -0.13% | -0.10% | -0.04% | 105% | 100% |
| 4.4.5.b | -0.21% | -0.34% | -0.41% | 103% | 98% | -0.08% | -0.11% | -0.10% | 105% | 100% |
| 4.4.5.c | -0.24% | -0.43% | -0.46% | 103% | 98% | -0.13% | -0.10% | -0.04% | 105% | 100% |
| 4.4.5 \* | -0.11% | -0.14% | -0.18% | 103% | 98% | -0.08% | -0.11% | -0.10% | 105% | 106% |

4.4.5\* is an encoder optimization that is done on top of VTM3. All other 4.4.5 results use this encoder optimization, but compare against VTM3 without it. 4.4.4.e is a combination of 4.4.5.c and 4.4.4.a, which additionally has some other encoder optimization.

4.4.1: The claimed benefit is that the number of context-coded bins in MVD coding is reduced from 4 to 1. This is achieved by joint coding of x and y differences, where the “layer” is the sum of x and y, and the index is an addressing in a layer. Index is coded as truncated binary (number of indices depends on the layer). In total, the number of bits for expressing the layer and the index is not changed relative to the independent coding of MVD.

Only the MVD coding part was changed, motion estimation, RDO etc. were identical.

4.4.1a is the simpler solution, difference in compression performance is marginal.

It was initially planned in Track B to adopt JVET-M0403 (test 4.4.1a, 2 layer groups, where the first group is just the 0,0 MVD).

Specification text was available.

In the Sunday plenary it was discussed that the benefit of context coding reduction in MVD coding is almost marginal, and might not justify changing a well established scheme. Further, in the context of later discussion related to CE8, it was detected that this might have coding efficiency problems with CPR. Furthermore, it would be more difficult to check in the layer/index representation if the CPR range constraints are valid. It was therefore agreed to revert the decision above (Thu. 17 Jan. afternoon).

4.4.3: The compression gain of symmetric MVD coding is 0.16% (was approx. 0.6% before), could be reduced by the fact that VTM3 incudes MMVD, which also uses symmetric coding, and also other elements of improved MV coding. Encoding time increases by 5%, very simple for decoder.

Some concern is expressed that not all of the current gain may be retained when MMVD would be further improved.

There was another contribution (JVET-M0444) which reported that by further encoder optimization and disallowing combination with BDOF further gain is possible. See further notes reported on discussion of the BoG report JVET-M0843.

Proposals related to MMVD:

4.4.4.a: Add diagonal direction candidates. This saves 0.13% for RA, 0.05% for LB, encoder time increases by about 5%.

4.4.4.b: Instead one list with 8 MVD, use two lists with 4 each, where the first list is narrow range, the second list wider range of differences. Whereas the maximum MVD in current design is 32, here it is suggested as 8. This has 0.05% gain for RA, 0.09% loss for LB. One more context coded bin. Encoding time is increased by 2%

4.4.4.c: Combination of a/b, giving 0.28% in RA. The new distance table seems to be more efficient for diagonal direction. Furthermore, 4.4.4.a has more encoding checks, which may be another reason.

It is noted that the VTM encoder has also a “non fast” MMVD check which also provides additional compression gain by doing more checks.

4.4.4.d: Integer rounding does not give benefit.

Not clear how much the elements of the proposal (introducing diagonal directions, and modifying the MVD coding) contribute to the compression gain, and how much is due to additional encoder optimization. Generally for LB, no benefit at all.

4.4.5.a is recording the occurrences of the different MVD for each picture, and reordering of the distances for the current picture is performed based on the data that were collected in the picture of list 0, refidx 0. Some mechanism providing a “score” for a table is used as well.

It is pointed out that explicit signalling would be at almost no rate increase and without additional decoding complexity, and also give up the dependency between slices. Generally, from the note on 4.4.5\* above, the benefit of reordering is relatively small (maybe in the range of 0.1%).

4.4.5.b makes the distance table dependent on picture resolution. The coding gain is observed mainly on 4K sequences (where a different table is used).

It is also pointed out that this could better be explicitly signalled rather than inferring it from the picture size. The signalling overhead would be low.

4.4.5.c is combination of a and b, where the gain seems not to be additive.

4.4.4.e is a combination of 4.4.4 and 4.4.5, where some more fast algorithm for 4.4.4.c is included.

The results of 4.4.4b and 4.4.5 indicate that some improvement could be possible by adapting/modifying the distance table, but it is not clear how much gain is due to encoder optimization as well. Further study is necessary, and there are also CE related proposals which may provide more information.

In upcoming experiments on MMVD, it should be observed that it is possible to judge the benefit of new normative aspects versus encoder optimization.

Proponents offer to provide additional results on just combining 4.4.4.a and 4.4.5.b. This should report results versus an anchor that is VTM3+4.4.5\*.

This was further discussed after such results were available (see JVET-M0854), and then also after review of non-CE proposals and an initial expectation of how many different new aspects would be investigated on MMVD in the next round of CE, decide whether such a combination could be a candidate for VTM4, or be further studied in the next round of CE as well.

The encoder optimization of 4.4.5\* is documented in JVET-M0823; it was cross-checked, and it was agreed that this would be a candidate for a software adoption.

4.2.5 (JVET-M0291) is also MMVD related. The following aspect are included:

- increase base candidates from 2 to 3, and decrease size of distance table from 8 to 4 (4.2.5.a)

- introduce diagonal directions, and decrease size of distance table from 8 to 4 (4.2.5.b)

A misalignment of software and text is also reported, where test 4.2.5.b follows the VVC3 spec which disables combination of MMVD with triangle mode, and with CIIP. This may give some additional gain.

4.2.5.a gives small loss (0.07%, 0.03%) in RA and LB

4.2.5.b gives loss in RA (0.02%), small gain (-0.07%) in LB. These compare against the anchor without the misalignment fix, which may mean that the results are worse both for RA and LB.

There is report about decoding time decrease, but it is unclear how around 5% could be explainable by just reducing the distance table from 8 to 4.

CE4.5: Motion compensation constraints for complexity reduction

|  |  |  |
| --- | --- | --- |
| **Test#** | **Source** | **Description** |
| 4.5.1 | JVET-M0313 | Disabling bi-prediction for 4x8 and 8x4 CUs |
| 4.5.2 | JVET-M0313 | Disabling bi-prediction or inter prediction for CU which memory bandwidth exceeds that of 8x8 bi-prediction: bi-prediction is disabled for 4×8, 8×4, 4×16 and 16×4 CUs, and inter prediction is disabled for 4×4 CUs. |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | **Low delay B Main10** | | | | |
| **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 4.5.1 | 0.09% | 0.19% | 0.25% | 99% | 96% | 0.13% | 0.08% | 0.31% | 99% | 105% |
| 4.5.2 | 0.32% | 0.71% | 0.81% | 99% | 97% | 0.49% | 0.88% | 0.80% | 98% | 99% |

The following table is provided:

|  |  |
| --- | --- |
| CU size (W×H) | Number of luma samples to be fetched per luma sample (W + 7) × (H + 7) / (W × H) |
| 8×8 Bi-prediction | **7.03** |
| 4×8 Bi-prediction | 10.31 |
| 4×16 Bi-prediction | 7.91 |
| 4×32 Bi-prediction | 6.70 |
| 4×64 Bi-prediction | 6.10 |
| 8×4 Bi-prediction | 10.31 |
| 16×4 Bi-prediction | 7.91 |
| 32×4 Bi-prediction | 6.70 |
| 64×4 Bi-prediction | 6.10 |
| 4×4 Uni-prediction | 7.56 |

It is noted that the table above does not consider memory access patterns, is only pixel level access.

Further study on these aspects is needed. There are also non-CE proposals which use other methods (e.g. shorter interpolation filters, integer pel, padding, …) which could be considered for reducing memory access.

Establish BoG (K. Zhang) to review the CE4 related proposals, and suggest aspects to be studied in CE. Consider either significant complexity reduction without losing compression performance, or proposals with significant improvement of compression without increasing complexity. If there are proposals that are closely related to proposals that were investigated in CE (e.g. some beneficial encoder optimization, or minor syntax change with benefit, or further complexity reduction), these should be reported to track B for possible consideration for adoption.

(include summaries of contribution from JVET-M0024 subsequently)

[JVET-M0059](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4861) CE4: Non-scaling STMVP (Test 4.2.1) [T. Zhou, T. Ikai (Sharp)]

[JVET-M0060](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4862) CE4: Enhanced Merge with MVD (Test 4.4.4) [T. Hashimoto, E. Sasaki, T. Ikai (Sharp)]

[JVET-M0061](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4863) CE4: Combination of CE4.4.4.a and CE4.4.5.c (Test 4.4.4.e) [T. Hashimoto, E. Sasaki, T. Ikai (Sharp), J. Li, R.-L. Liao, C. S. Lim (Panasonic)]

[JVET-M0687](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5509) Crosscheck of JVET-M0061 (CE4.4.4e: Combination of CE4.4.4.a and CE4.4.5.c) [L. Xu, F. Chen, L. Wang (Hikvision)] [late]

[JVET-M0086](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4889) CE4: Non-sub-block ATMVP (test 2.5.4) [K. Abe, T. Toma (Panasonic)]

[JVET-M0106](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4911) CE4: STMVP without scaling (tests 4.2.2) [F. Le Léannec, T. Poirier, F. Galpin (Technicolor)]

[JVET-M0124](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4929) CE4: Methods of Reducing Number of Pruning Checks of History Based Motion Vector Prediction (Test 4.1.1) [J. Zhao, S. Kim (LGE)]

[JVET-M0126](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4931) CE4: Modification on History-based Motion Vector Prediction [Y. Han, W.-J. Chien, C.-C. Chen, H. Huang, C.-H. Hung, Y. Zhang, M. Karczewicz (Qualcomm)]

[JVET-M0826](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5657) Crosscheck of JVET-M0126 supplemental data (CE4: Modification on history-based motion vector prediction) [Y.-C. Lin (MediaTek)] [late]

[JVET-M0170](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4977) CE4.3.1: Shared merging candidate list [C.-C. Chen, Y.-C. Lin, M.-S. Chiang, C.-W. Hsu, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0584](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5401) Crosscheck of JVET-M0170 (CE4: Modification on History-based Motion Vector Prediction) Supplementary Tests [Y. Han, H. Wang, C.-C. Chen, W.-J. Chien (Qualcomm)] [late]

Note: Title of crosscheck is wrong – should be CE4.3.1: Shared merging candidate list

[JVET-M0221](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5028) CE4: STMVP simplification (test 4.2.3a) [Y.-H. Chao, Y. Han, W.-J. Chien, M. Karczewicz (Qualcomm)]

[JVET-M0281](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5088) CE4: Inter motion predictor pruning (test 4.1.5) [A. Robert, F. Le Léannec, T. Poirier, F. Galpin (Technicolor)]

[JVET-M0289](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5096) CE4: Parallel Merge Estimation for VVC (Test 4.3.2) [H. Gao, S. Esenlik, B. Wang, A.M. Kotra, J. Chen (Huawei)]

[JVET-M0291](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5098) CE4: Extension on MMVD (Test 4.2.5) [X. Chen, J. Zheng (HiSilicon)]

[JVET-M0686](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5508) Crosscheck of JVET-M0291 (CE4.2.5: Extension on MMVD) [L. Xu, F. Chen, L. Wang (Hikvision)] [late]

[JVET-M0312](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5119) CE4: MMVD improvement (test 4.4.5) [J. Li, R.-L. Liao, C. S. Lim (Panasonic)]

[JVET-M0867](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5698) Crosscheck of CE4.4.5\* [E. Sasaki, T. Ikai (Sharp)] [late]

[JVET-M0313](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5120) CE4: Motion compensation constraints for complexity reduction (test 4.5.1 and test 4.5.2) [R.-L. Liao, J. Li, C. S. Lim (Panasonic)]

[JVET-M0403](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5211) CE4: Generic Vector Coding of Motion Vector Difference (Tests 4.4.1.a and 4.4.1.b) [S. Paluri, M. Salehifar, S. Kim (LGE)]

[JVET-M0698](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5520) Crosscheck of JVET-M0403: CE4: Generic Vector Coding of Motion Vector Difference (Tests 4.4.1.a and 4.4.1.b) [L. Pham Van, W.-J. Chien, M. Karczewicz (Qualcomm)] [late]

[JVET-M0404](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5212) CE4: History based spatial-temporal MV prediction (Test 4.2.4) [X. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0481](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5291) CE4: Symmetrical MVD mode (Test 4.4.3) [H. Chen, T. Solovyev, H. Yang, J. Chen (Huawei)]

## CE5: Arithmetic coding engine (10)

Contributions in this category were discussed Thursday 10 January 1700–2030 (in Track A chaired by Y. Ye).

[JVET-M0025](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5398) 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. Subtest 1 (experiments CE5.1.1 – 5.1.13) addresses the effect on the compression efficiency of training parameters of the probability estimation stage of the proposed arithmetic coding engines. Subtest 2 addresses the achievable throughput of the different coding engines of subtest 1 in an optimized software implementation. Subtest 3 provides a summary of the analysis of hardware implementation aspects.

The experiments were implemented in separate branches in the following git repository:

<https://vcgit.hhi.fraunhofer.de/JVET-L-CE5/VVCSoftware_VTM.git>

For subtest 2, a testbed is available in branch CE5.2, which contains throughput-optimized software implementations of the coding engines of subtest 1.

The following table lists all tests that were performed in this CE and gives a summary of the tools.

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 with retrained parameters** | | | |
| **CE # (Proponent)** | **Related Docs.** | **Summary of the tool** | **Crosscheckers** |
| 5.1.1 (HHI) | JVET-M0725 | 2 linear states (10+14 bits), fixed | MediaTek |
| 5.1.2 (HHI) | JVET-M0725 | 2 linear states (10+14 bits), variable | MediaTek |
| 5.1.3 (Qualcomm) | JVET-M0412 | 2 linear states (10+14 bits), variable: Configuration 1: Coding interval subdivision from JVET-L0335 is used Configuration 2: Coding interval subdivision from JVET-L0117 is used | HHI |
| 5.1.4 (Qualcomm) | JVET-M0413 | 1 linear state (14 bits), variable: Configuration 1: Coding interval subdivision from JVET-L0335 is used Configuration 2: Coding interval subdivision from JVET-L0117 is used | Sharp Labs |
| 5.1.5 (HHI) | JVET-M0727 | 2 log. states (8+12 bits), fixed | Sharp Labs |
| 5.1.6 (HHI) | JVET-M0727 | 2 log. states, variable Configuration 1: 8+12 bits Configuration 2: 10+14 bits | Sharp Labs |
| 5.1.7 (HHI) | JVET-M0727 | 1 log. state (12 bits), variable | Sharp Labs |
| 5.1.8 (Samsung) | JVET-M0199 | 2 linear states (15+15 bits), fixed  Only the short window size model is updated for the first 31 bins of a context model. | MediaTek |
| 5.1.9 (MediaTek) | JVET-M0172 | 2 linear states (10+14 bits), fixed Multiplier-based coding interval subdivision.  Configuration 1: 6-bit by 5-bit multiplier.  Configuration 2: 6-bit by 4-bit multiplier.  Both configurations can implemented as 32x8x8 bit LUT. | Samsung |
| 5.1.10 (Sharp Labs) | JVET-M0453 | 2 linear states, fixed Uses 2b−1 instead of 2b in probability update | HHI |
| 5.1.11 (Sharp Labs) | JVET-M0453 | 2 linear states, variable Uses 2b−1 instead of 2b in probability update | HHI |
| 5.1.12 (Sharp Labs) | JVET-M0453 | 1 linear state, variable Uses 2b−1 instead of 2b in probability update | MediaTek |
| 5.1.13 (Sharp Labs) | JVET-M0453 | 2 linear states, variable Uses 2b−1 instead of 2b in probability update Uses 5x4 multiplier for coding interval subdivision | HHI |

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **AI** | | | | **RA** | | | | **LB** | | | |
| **CE #** | Y | U | V | EncT/ DecT (%) | Y | U | V | EncT/ DecT (%) | Y | U | V | EncT/ DecT (%) |
| 5.1.1 | -0,81% | -1,15% | -1,20% | 105/101 | -0,71% | -1,06% | -0,97% | 102/100 | -0,60% | -0,22% | -0,18% | 102/100 |
| 5.1.2 | -0,97% | -1,18% | -1,27% | 107/101 | -0,97% | -0,99% | -0,93% | 103/99 | -0,89% | -0,08% | -0,25% | 102/99 |
| 5.1.3.1 | -0,95% | -1,35% | -1,44% | 107/103 | -0,90% | -1,06% | -0,97% | 105/106 | -0,77% | -0,01% | -0,23% | 106/103 |
| 5.1.3.2 | -0,99% | -1,42% | -1,53% | 107/105 | -0,95% | -1,07% | -1,04% | 106/106 | -0,82% | -0,04% | -0,15% | 107/104 |
| 5.1.4.1 | -0,80% | -1,12% | -1,11% | 108/107 | -0,64% | -0,11% | -0,01% | 107/110 | -0,56% | 1,01% | 1,51% | 107/104 |
| 5.1.4.2 | -0,89% | -1,21% | -1,18% | 108/107 | -0,71% | -0,26% | -0,05% | 108/109 | -0,61% | 1,02% | 1,76% | 107/107 |
| 5.1.5 | -0,76% | -1,47% | -1,41% | 101/98 | -0,63% | -0,79% | -0,70% | 97/93 | -0,68% | -0,29% | 0,08% | 94/91 |
| 5.1.6.1 | -0,83% | -1,51% | -1,53% | 103/98 | -0,76% | -0,77% | -0,75% | 98/93 | -0,76% | -0,44% | -0,15% | 95/92 |
| 5.1.6.2 | -0,91% | -1,44% | -1,44% | 104/97 | -0,81% | -0,92% | -0,85% | 98/93 | -0,72% | -0,42% | -0,05% | 95/92 |
| 5.1.7 | -0,66% | -1,12% | -1,10% | 100/98 | -0,53% | -0,96% | -0,95% | 97/93 | -0,52% | -0,66% | -0,52% | 94/92 |
| 5.1.8 | -0,86% | -1,36% | -1,37% | 106/101 | -0,68% | -0,86% | -0,71% | 102/101 | -0,53% | -0,60% | 0,51% | 99/95 |
| 5.1.9.1 | -0,79% | -1,05% | -1,18% | 105/101 | -0,57% | -1,05% | -1,00% | 102/100 | -0,50% | -0,82% | -0,66% | 103/101 |
| 5.1.9.2 | -0,76% | -1,02% | -1,15% | 105/102 | -0,55% | -1,03% | -0,98% | 102/100 | -0,49% | -0,81% | -0,65% | 102/101 |
| 5.1.10 | -0,79% | -1,10% | -1,16% | 108/104 | -0,67% | -1,06% | -1,02% | 104/102 | -0,54% | -0,38% | -0,78% | 103/101 |
| 5.1.11 | -0,94% | -1,14% | -1,23% | 108/103 | -0,93% | -0,95% | -1,05% | 103/101 | -0,80% | -0,27% | -0,38% | 102/101 |
| 5.1.12 | -0,66% | -0,74% | -0,50% | 108/103 | -0,55% | 0,18% | 0,94% | 102/100 | -0,54% | 0,81% | 2,33% | 101/99 |
| 5.1.13 | -0,93% | -1,13% | -1,21% | 109/103 | -0,91% | -0,93% | -1,03% | 104/101 | -0,78% | -0,24% | -0,35% | 101/98 |
| 2 states variable, 2 states fixed, 1 state variable | | | | | | | | | | | | |

It was reported that some of the encoding/decoding time in the table may not be reliable. It was commented that these tests have similar encoding/decoding time, and variation is in the noise range.

The CABAC engine and the initialization states are tested together.

VTM 3 uses HEVC CABAC engine with the following characteristics:

* 1 log. state, 7 bits, fixed window size
* Coding interval subdivision of 64x4x8 bits LUT

Throughput-optimized software implementations of the configurations in CE5.1 are tested in terms of the achievable throughput in the decoder. Two types of bin sequences are used for the evaluation:

* VTM3: Bin sequences extracted from VTM-3.0 CTC bitstreams
* RND: Randomly generated bin sequences

Three contributions report results for CE5.2:

* JVET-M0453 (Sharp)
* JVET-M0463 (Qualcomm)
* JVET-M0762 (HHI)

It was commented that JVET-M0453 and JVET-M0463 reported consistent trends in terms of throughput numbers for the CE tests. JVET-M0762 was a late contribution that was updated shortly before the CE review started. It was agreed to review JVET-M0762 for further discussion of this CE. See notes under JVET-M0762.

[JVET-M0172](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4979) CE5.1.9: CABAC engine with simplified range sub-interval derivation [T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0199](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5006) CE5: Counter-based probability estimation (CE5.1.8) [K. Choi, Y. Piao (Samsung)]

[JVET-M0412](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5221) CE5: Per-context CABAC initialization with double windows (Test 5.1.3) [A. Said, J. Dong, H. Egilmez, Y.-H. Chao, M. Karczewicz, V. Seregin (Qualcomm)]

[JVET-M0413](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5222) CE5: Per-context CABAC initialization with single window (Test 5.1.4) [A. Said, J. Dong, H. Egilmez, Y.-H. Chao, M. Karczewicz, V. Seregin (Qualcomm)]

[JVET-M0453](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5262) CE5 on arithmetic coding: experiments 5.1.1, 5.1.2, 5.1.3, 5.1.4, 5.1.5, 5.1.6, 5.1.7, 5.1.8, 5.1.10, 5.1.11, 5.1.12, 5.1.13, 5.2, and more [F. Bossen (Sharp)]

This report provides results for the following CE5 experiments: 5.1.1, 5.1.2, 5.1.3, 5.1.4, 5.1.5, 5.1.6, 5.1.7, 5.1.8, 5.1.10, 5.1.11, 5.1.12, 5.1.13 and 5.2. Additional variants of these experiments are considered where constants, such as initial state values and shift amounts, are modified.

Version 2 of the document provides additional results for experiment 5.2 on throughput, as well as BD-rate results for a configuration that yields no encoder run time increase.

The following table reports the decoder throughput from an actual bin stream (first 10 million context-coded bins from ParkRunning, RA configuration, QP22). Three compilers have been tested: clang 10.0 (Apple LLVM version 10.0.0), gcc 7.4 (Homebrew GCC 7.4.0) and gcc 8.2 (Homebrew GCC 8.2.0). The test bed was configured with the macro NOBRANCH\_MPS either on (left half of table) or off (right half of table). Results were obtained on an Intel® Xeon® W-2140B CPU @ 3.20GHz.

In almost all cases the combination of clang and NOBRANCH\_MPS enabled yielded the highest throughput. This configuration is thus considered for comparing the various engines.

The rightmost column in the table below reports the decoder throughput for a different bin stream (first 10 million context-coded bins from BQTerrace, RA configuration, QP22, clang, NOBRANCH\_MPS enabled).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Engine | clang | gcc 7 | gcc 8 | clang | gcc 7 | gcc 8 | clang stream #2 |
| AVC/HEVC CABAC | 132.03 | 134.92 | 128.64 | 127.27 | 121.13 | 124.98 | 137.88 |
| CE5.1.1 | 120.17 | 117.48 | 118.58 | 113.54 | 108.52 | 109.26 | 121.51 |
| CE5.1.2 | 115.00 | 110.93 | 113.28 | 104.01 | 108.47 | 102.20 | 114.67 |
| CE5.1.3 | 106.63 | 104.98 | 104.60 | 95.89 | 96.84 | 96.37 | 102.79 |
| CE5.1.4 | 109.09 | 106.68 | 107.28 | 104.77 | 104.45 | 104.77 | 110.55 |
| CE5.1.4 mult | 134.85 | 133.09 | 131.12 | 120.09 | 116.32 | 117.72 | 135.13 |
| CE5.1.5 | 113.46 | 106.75 | 107.56 | 111.67 | 102.44 | 104.75 | 113.02 |
| CE5.1.6 (8+12 bit) | 110.75 | 105.07 | 103.62 | 103.64 | 98.89 | 100.07 | 108.50 |
| CE5.1.7 | 119.00 | 110.98 | 112.45 | 118.51 | 110.15 | 107.84 | 120.23 |
| CE5.1.8 | 118.80 | 114.27 | 107.99 | 107.71 | 103.96 | 100.47 | 119.39 |
| CE5.1.9 / CE 5.1.10 | 125.05 | 122.68 | 120.02 | 120.47 | 113.33 | 115.96 | 127.29 |
| CE5.1.11 | 121.79 | 117.33 | 117.14 | 107.25 | 113.08 | 111.22 | 123.35 |
| CE5.1.12 | 128.95 | 123.80 | 127.78 | 118.60 | 119.66 | 120.22 | 129.01 |
| CE5.1.13 / CE5.1.3 mult | 127.28 | 121.00 | 122.57 | 109.90 | 109.25 | 110.67 | 127.32 |

Experiments were run a second time, where each test is done 7 times and the highest throughput value is recorded. While the numbers are slightly higher, the same trends persist.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Engine | clang | gcc 7 | gcc 8 | clang | gcc 7 | gcc 8 | clang stream #2 |
| AVC/HEVC CABAC | 137.27 | 137.83 | 131.01 | 131.69 | 124.68 | 127.93 | 141.37 |
| CE5.1.1 | 124.17 | 121.64 | 120.26 | 117.41 | 112.53 | 110.42 | 124.48 |
| CE5.1.2 | 116.69 | 115.36 | 116.85 | 106.22 | 110.39 | 109.24 | 115.93 |
| CE5.1.3 | 107.96 | 106.13 | 105.99 | 96.69 | 98.59 | 97.68 | 108.09 |
| CE5.1.4 | 111.83 | 109.14 | 109.93 | 106.80 | 106.21 | 106.51 | 112.09 |
| CE5.1.4 mult | 136.30 | 133.96 | 132.36 | 120.85 | 116.32 | 121.01 | 137.27 |
| CE5.1.5 | 115.84 | 109.11 | 108.83 | 114.71 | 105.29 | 105.21 | 115.73 |
| CE5.1.6 (8+12 bit) | 112.69 | 106.88 | 103.99 | 105.00 | 102.27 | 102.21 | 112.68 |
| CE5.1.7 | 120.75 | 112.94 | 113.24 | 119.12 | 106.58 | 114.97 | 120.89 |
| CE5.1.8 | 122.01 | 116.04 | 108.10 | 110.09 | 107.50 | 102.54 | 125.28 |
| CE5.1.9 / CE 5.1.10 | 128.67 | 124.20 | 121.22 | 122.22 | 119.20 | 117.55 | 129.44 |
| CE5.1.11 | 124.55 | 118.73 | 119.37 | 114.53 | 114.48 | 112.39 | 125.28 |
| CE5.1.12 | 130.26 | 128.17 | 130.77 | 121.13 | 121.84 | 120.45 | 131.45 |
| CE5.1.13 / CE5.1.3 mult | 128.51 | 122.63 | 126.85 | 112.10 | 111.23 | 112.96 | 128.87 |

It was agreed that the second table of throughput numbers had much lower probability of having outlier values in it.

The table below summarizes the performance of various arithmetic coding engines, classifying them in three groups:

* Two states, fixed window sizes
* Two states, variable (context-adaptive) window sizes
* Single state, variable (context-adaptive) window sizes

BD rate numbers are reported as combined YUV, where BD rate numbers for Y, U and V are weighted as 90%/5%/5% to obtain a single number. This is done to account for the fact that results for individual color components can sometimes diverge.

Also provided for each engine are encoder/decoder run times relative to VTM3, as well as SW throughput results from experiment 5.2.

Within each group and each test condition the best BD rate and throughput results are highlighted in green. The worst results are highlighted in red.

Experiment numbers with a star indicate a variant, where some constants are modified as described.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Engine** | **AI** | **RA** | **LB** | **LP** | **AI** | **RA** | **LB** | **Thruput** |
| **2 states, fixed window size** |  |  |  |  |  |  |  |  |
| 5.1.1 | -0.85% | -0.74% | -0.56% | -0.56% | 106/103 | 103/102 | 101/100 | 120.17 |
| 5.1.5 | -0.83% | -0.64% | -0.62% | -0.60% | 109/107 | 105/103 | 103/103 | 113.46 |
| 5.1.8 | -0.91% | -0.69% | -0.48% | -0.50% | 106/102 | 103/101 | 100/98 | 118.80 |
| 5.1.10 | -0.83% | -0.70% | -0.55% | -0.61% | 108/104 | 104/102 | 103/101 | 125.05 |
| 5.1.10\* + new init from 5.1.2 | -0.84% | -0.73% | -0.51% | -0.53% | 109/107 | 105/104 | 105/104 | 125.05 |
| 5.1.10\* 5x6 mult | -0.85% | -0.73% | -0.58% | -0.64% | 109/107 | 105/104 | 104/104 | 127.86 |
| **2 states, variable window size** |  |  |  |  |  |  |  |  |
| 5.1.2 | -1.00% | -0.97% | -0.82% | -0.76% | 109/105 | 104/103 | 101/101 | 115.00 |
| 5.1.3 clz + 8x8 table | -1.03% | -0.96% | -0.74% | -0.83% | 107/108 | 104/104 | 104/104 | 106.63 |
| 5.1.3 4x5 mult | -0.99% | -0.91% | -0.71% | -0.83% | 109/105 | 104/102 | 103/102 | 127.28 |
| 5.1.3\* 5x6 mult | -1.07% | -0.99% | -0.79% | -0.91% | 108/104 | 104/103 | 104/103 | 127.28 |
| 5.1.6 8+12 bit state | -0.90% | -0.76% | -0.72% | -0.69% | 111/105 | 105/103 | 105/102 | 110.75 |
| 5.1.6 10+14 bit state | -0.97% | -0.82% | -0.67% | -0.73% | 112/105 | 105/102 | 105/102 | 110.75 |
| 5.1.11 | -0.97% | -0.93% | -0.75% | -0.76% | 108/103 | 103/101 | 102/101 | 121.79 |
| 5.1.11\* + new init from 5.1.2 | -1.00% | -0.98% | -0.77% | -0.75% | 110/105 | 104/102 | 104/102 | 121.79 |
| 5.1.13 | -0.95% | -0.91% | -0.73% | -0.74% | 109/103 | 104/101 | 101/98 | 127.28 |
| 5.1.13\* +new init from 5.1.2 | -0.98% | -0.96% | -0.75% | -0.73% | 110/105 | 104/103 | 106/103 | 127.28 |
| 5.1.13\* 5x6 mult | -1.03% | -0.98% | -0.75% | -0.75% | 109/105 | 104/102 | 104/104 | 127.28 |
| **1 state, variable window size** |  |  |  |  |  |  |  |  |
| 5.1.4 clz + 8x8 table | -0.92% | -0.65% | -0.41% | -0.44% | 108/107 | 103/104 | 104/103 | 109.09 |
| 5.1.4 4x5 mult | -0.83% | -0.58% | -0.37% | -0.41% | 108/105 | 104/102 | 102/102 | 132.95 |
| 5.1.4\* 5x6 mult | -0.93% | -0.67% | -0.46% | -0.49% | 107/105 | 104/102 | 104/103 | 132.95 |
| 5.1.7 | -0.70% | -0.57% | -0.53% | -0.52% | 107/107 | 104/103 | 103/104 | 119.00 |
| 5.1.12 | -0.65% | -0.44% | -0.33% | -0.25% | 108/103 | 102/100 | 101/99 | 128.95 |

The table above was copied from JVET-M0453 and then updated in group discussion to form the modified table below. The each category in the table was reviewed and particular tests that provided the highest coding efficiency in each category with good throughput numbers were highlighted for further focused discussion. The properties, similarities and differences between the tested methods were discussed.

The following table was obtained by updating the table above as follows: 1) adding 5.1.9, 2) replacing throughput numbers with the second throughput number table, and 3) keeping only rows that pertain to the CE tests.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Engine** | **AI** | **RA** | **LB** | **LP** | **AI** | **RA** | **LB** | **Thruput** |
| **VTM3 w/ HEVC engine** | 0 | 0 | 0 | 0 | 100/100 | 100/100 | 100/100 | 137.83 |
| **2 states, fixed window size** |  |  |  |  |  |  |  |  |
| 5.1.1 | -0.85% | -0.74% | -0.56% | -0.56% | 106/103 | 103/102 | 101/100 | 124.17 |
| 5.1.5 | -0.83% | -0.64% | -0.62% | -0.60% | 109/107 | 105/103 | 103/103 | 115.84 |
| 5.1.8 | -0.91% | -0.69% | -0.48% | -0.50% | 106/102 | 103/101 | 100/98 | 122.01 |
| 5.1.9 | -0.79% | -0.57% | -0.50% | N/A |  |  |  | 128.67 |
| 5.1.10 | -0.83% | -0.70% | -0.55% | -0.61% | 108/104 | 104/102 | 103/101 | 128.67 |
| 5.1.10\* + new init from 5.1.2 | -0.84% | -0.73% | -0.51% | -0.53% | 109/107 | 105/104 | 105/104 | 128.67 |
| **2 states, variable window size** |  |  |  |  |  |  |  |  |
| 5.1.2 | -1.00% | -0.97% | -0.82% | -0.76% | 109/105 | 104/103 | 101/101 | 116.69 |
| 5.1.3 clz + 8x8 table (config. 2) | -1.03% | -0.96% | -0.74% | -0.83% | 107/108 | 104/104 | 104/104 | 107.96 |
| 5.1.3 4x5 mult (config. 1) | -0.99% | -0.91% | -0.71% | -0.83% | 109/105 | 104/102 | 103/102 | 128.51 |
| 5.1.6 8+12 bit state | -0.90% | -0.76% | -0.72% | -0.69% | 111/105 | 105/103 | 105/102 | 112.69 |
| 5.1.6 10+14 bit state | -0.97% | -0.82% | -0.67% | -0.73% | 112/105 | 105/102 | 105/102 | 112.69\* |
| 5.1.11 | -0.97% | -0.93% | -0.75% | -0.76% | 108/103 | 103/101 | 102/101 | 124.55 |
| 5.1.11\* + new init from 5.1.2 | -1.00% | -0.98% | -0.77% | -0.75% | 110/105 | 104/102 | 104/102 | 124.55 |
| 5.1.13 | -0.95% | -0.91% | -0.73% | -0.74% | 109/103 | 104/101 | 101/98 | 128.51 |
| 5.1.13\* +new init from 5.1.2 | -0.98% | -0.96% | -0.75% | -0.73% | 110/105 | 104/103 | 106/103 | 128.51 |
| **1 state, variable window size** |  |  |  |  |  |  |  |  |
| 5.1.4 clz + 8x8 table (config. 2) | -0.92% | -0.65% | -0.41% | -0.44% | 108/107 | 103/104 | 104/103 | 111.83 |
| 5.1.4 4x5 mult (config. 1) | -0.83% | -0.58% | -0.37% | -0.41% | 108/105 | 104/102 | 102/102 | 136.30 |
| 5.1.7 | -0.70% | -0.57% | -0.53% | -0.52% | 107/107 | 104/103 | 103/104 | 120.75 |
| 5.1.12 | -0.65% | -0.44% | -0.33% | -0.25% | 108/103 | 102/100 | 101/99 | 130.77 |

It was suggested to look at the hardware aspect of these different engines, which was provided as part of JVET-M0025 subtest 3.

It was agreed that no hardware problem had been identified for any of the CE tests, and that such a hardware problem could be fixed if/when it was identified.

When looking at different categories, it was remarked that the “1 state, variable window” category has the highest throughput (closest to HEVC engine), and the “2 state, variable window” category has the highest coding performance. Regarding the “2 state, fixed window” category, it was remarked that this category does not need custom window size parameters for different context models, but needs re-training of initialization parameters.

Regarding custom window size parameters, it was remarked that that does not seem to increase complexity to such a degree that it justifies going for a simpler solution (i.e. fixed window size).

It was remarked that some of the coding efficiency gain from the tests that use custom window size parameters may have come from training of custom window size parameters based on the test set.

It was remarked that the initialization parameters were also trained on the test set, which also may have provided some of the coding efficiency gain.

In terms of coding efficiency, the options “5.1.3 4x5 mult (config. 1)”, “5.1.13” and “5.1.13\* +new init from 5.1.2” are the most attractive options. Between “5.1.3” and “5.1.13,” the latter has a slight advantage for hardware implementations due to needing to support fewer shift values. And the difference between “5.1.13” and “5.1.13\* +new init from 5.1.2” is purely due to training of initialization parameters, with the new initialization parameters providing better coding efficiency.

Decision: adopt “5.1.13\* +new init from 5.1.2”

[JVET-M0463](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5272) CE5: Report of throughput analysis of CE5 contributions (CE5.2) [J. Dong, A. Said, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-M0725](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5552) CE5: Results of tests CE5.1.1 and CE5.1.2 [J. Stegemann, H. Kirchhoffer, H. Schwarz, D. Marpe, T. Wiegand (HHI)] [late]

[JVET-M0727](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5556) CE5: Results of tests CE5.1.5, CE5.1.6, and CE5.1.7 [H. Kirchhoffer, C. Bartnik, P. Haase, S. Matlage, J. Stegemann, D. Marpe, H. Schwarz, T. Wiegand (HHI)] [late]

[JVET-M0759](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5590) CE5: Report of subtest 3 on complexity and throughput aspects for hardware [B. Stabernack (HHI), T. Hsieh (Qualcomm)] [late]

[JVET-M0762](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5593) CE5: Report of software throughput analysis for CE5.2 by HHI [H. Kirchhoffer, C. Bartnik, T. Hinz, J. Stegemann, P. Haase, S. Matlage, B. Stabernack, H. Schwarz, D. Marpe, T. Wiegand (HHI)] [late]

This contribution presents results for CE5 subtest 2. The throughput measurement testbed as implemented in CE5.2 was used to produce throughput numbers for the test configurations of subtest 1.

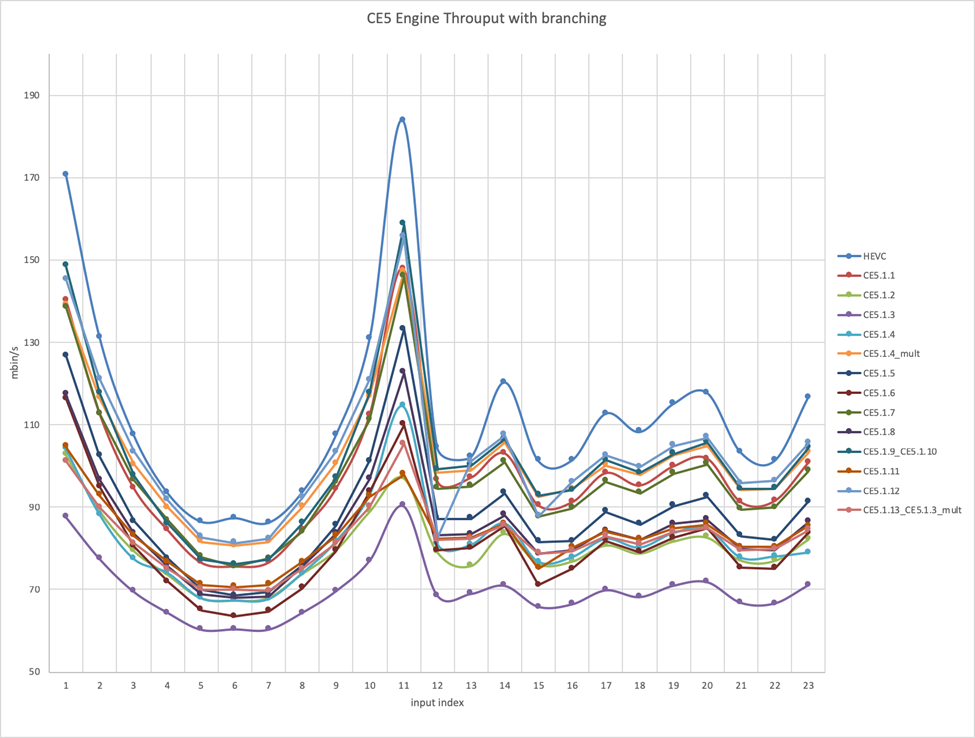
The throughput numbers in version 1 of this document contained a bug. They are replaced with corrected values in version 2.

The preprocessor macros of the testbed software of the CE5.2 branch are set according to the following table from JVET-M0453-r1, section 3.1.

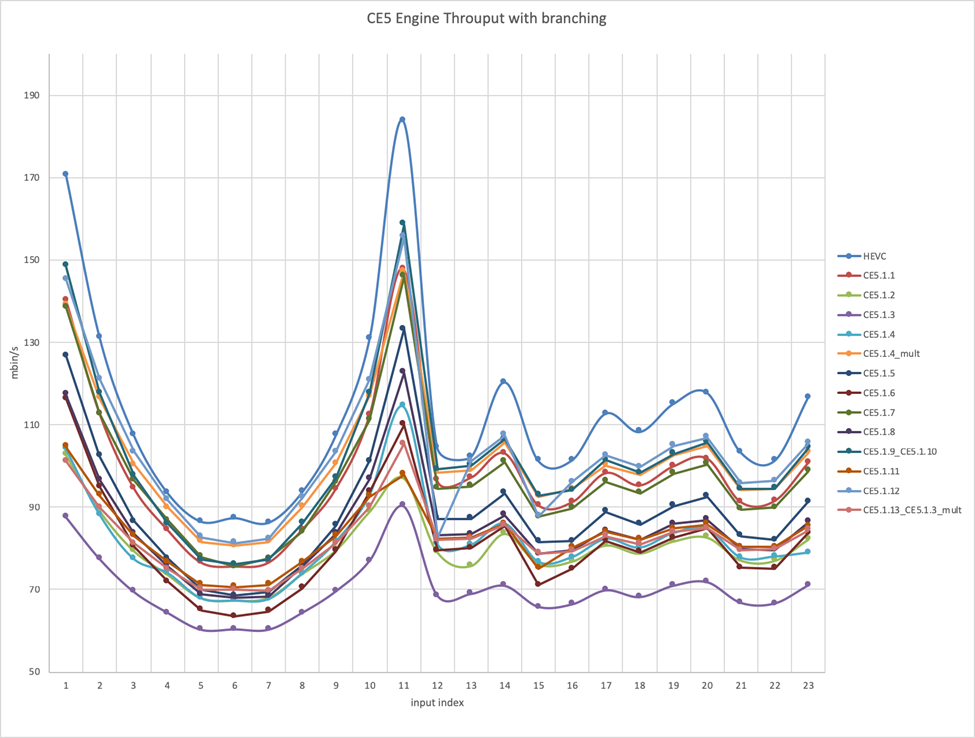
The throughput is measured for 11 synthetical bin sequences and 12 VTM-3.0 bitstreams.

Three combinations of two macros (NOBRANCH\_MPS and NOBRANCH) were tested as follows.

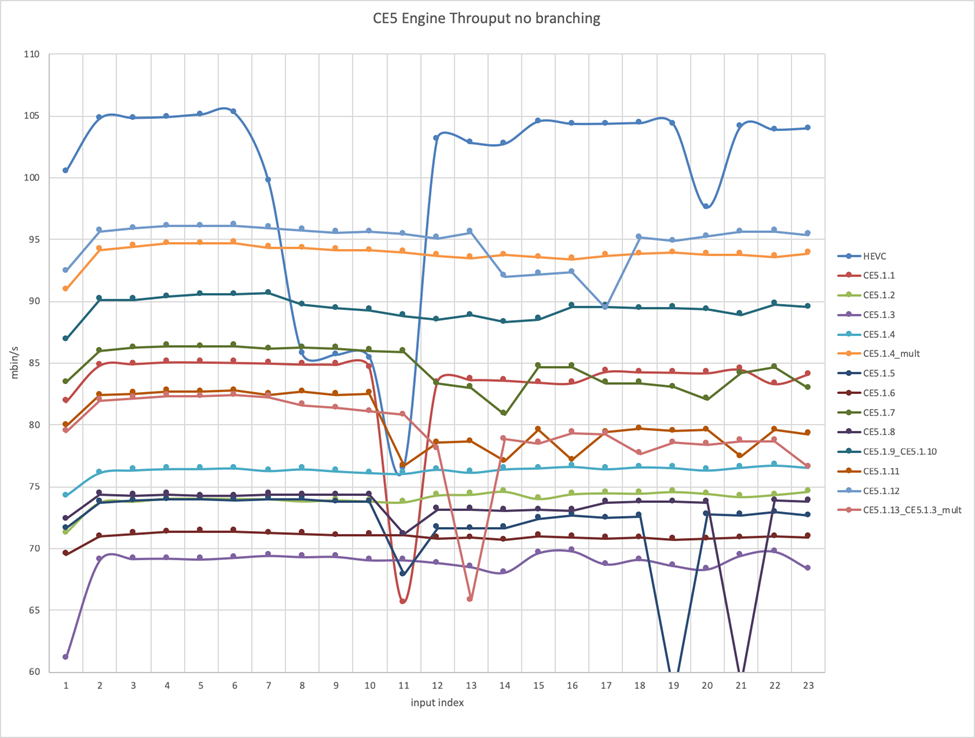
2.1 NOBRANCH off, NOBRANCH\_MPS off



2.2 (NOBRANCH off, NOBRANCH\_MPS on



2.3 (NOBRANCH on, NOBRANCH\_MPS on



It was commented that these graphs contained outliers. It was also commented that the graphs were uploaded very late (~20 minutes before the CE5 discussion started). It was then agreed to review JVET-M0453 instead, which provided throughput numbers for each CE test, for the further discussion of this CE. See notes under JVET-M0453.

## CE6: Transforms and transform signalling (21)

Contributions in this category were discussed Thursday 10 January 2030–2230, Friday 11 January 0900–1100, 1130–1400, and 1530–2000 (chaired by GJS).

[JVET-M0026](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5343) CE6: Summary Report on Transforms and Transform Signaling [A. Said, X. Zhao]

This contribution summarizes the activities of Core Experiment (CE) on Transforms and Transform Signaling. 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: Transform core design (19 tests, 7 proposals)

(2) CE6.2: Fast transform (3 tests, 3 proposals)

(3) CE6.3: Transform selection and signalling (10 tests, 5 proposals)

(4) CE6.4: Sub-block transform (8 tests, 4 proposals)

(5) CE6.5: Secondary transform (1 tests, 1 proposal)

In this CE all experiments were done using based on the VTM 3.0 software with a bug-fix for low QP configuration (without which the encoder could crash, a fix having no impact on CTC results since the CTC didn’t use extremely low QP values). This document summarizes the test results, brief experiment definition, cross-check reports and complexity measurements.

For all tests, two configurations were tested: CTC and CTC+Inter MTS. For this meeting report, only the CTC tables were included. The M0026 document contains the other tables as well.

For CE6.1 and CE6.2, additional low QP tests were done for QP values 1, 5, 9, 13, using only 100 frames of each test sequence (since the encoding is very slow at these QP values).

CE6-1 Transform core design

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CE6.1: Transform core design** | | | | |
| **Test #** | **Docs.** | **Description** | **Tester** | **Cross-checker** |
| 6-1.1a | JVET-M0496 | JVET-L0287: Replacing 4-pt DST-7 / DCT-8 by 4-pt DST-4 / DCT-4 used in MTS | X. Zhao (Tencent) | A. Karabutov (Huawei) |
| 6-1.1b | JVET-L0287: Replacing 4-pt and 8-pt DST-7 / DCT-8 by 4-pt and 8-pt DST-4 / DCT-4 used in MTS, respectively. | X. Zhao (Tencent) | A. Karabutov (Huawei) |
| 6-1.1c | JVET-L0287: Compound Orthonormal Transform | X. Zhao (Tencent) | A. Karabutov (Huawei) |
| 6-1.1d | 6-1.1c + 6.2.3a | X. Zhao (Tencent) | A. Karabutov (Huawei) |
| 6-1.1e | JVET-M0084 | JVET-L0262: Replacing all DST-7 / DCT-8 by DST-4 / DCT-4 used in MTS | K. Abe (Panasonic)  Sony  Technicolor | A. Karabutov (Huawei) |
| 6-1.2a | JVET-M0200 | JVET-L0060: Unified matrix for transform | K. Choi (Samsung) | X. Zhao (Tencent) |
| 6-1.3a | JVET-M0244 | JVET-L0353: MTS using DST-4 and transposed DCT-2 | Y. Lin (HiSilicon) | H. Egilmez (Qualcomm) |
| 6-1.3b | MTS using DCT-2 like transforms | Y. Lin (HiSilicon) | H. Egilmez (Qualcomm) |
| 6-1.4a | JVET-M0538 | JVET-L0386, JVET-L0682: TAF for 32-pt MTS | A. Said (Qualcomm) | A. Karabutov (Huawei)  X. Zhao (Tencent) |
| 6-1.4b | JVET-L0386, JVET-L0682: TAF for 32-pt and 64-pt MTS | A. Said (Qualcomm) | A. Karabutov (Huawei) |
| 6-1.4c | JVET-L0386, JVET-L0682: TAF for 16-pt and 32-pt MTS | A. Said (Qualcomm) | A. Karabutov (Huawei)  X. Zhao (Tencent) |
| 6-1.4d | JVET-L0386, JVET-L0682: TAF for 16-pt, 32-pt and 64-pt MTS | A. Said (Qualcomm) | A. Karabutov (Huawei) |
| 6-1.5a | JVET-M0080 | JVET-L0135: TAF simplification for 32-pt MTS | P. Philippe (Orange) | LGE |
| 6-1.5b | JVET-L0135: TAF simplification for 32-pt and 64-pt MTS | P. Philippe (Orange) | LGE |
| 6-1.5c | JVET-L0135: TAF simplification for 16-pt and 32-pt MTS | P. Philippe (Orange) | LGE |
| 6-1.5d | JVET-L0135: TAF simplification for 16-pt, 32-pt and 64-pt MTS | P. Philippe (Orange) | LGE |
| 6-1.6a | JVET-M0521 | JVET-L0395:4-pt DST-4 and DCT-4 replacing DST-7 and DCT-8 used in MTS | H. Egilmez (Qualcomm) | Y. Lin (HiSilicon) |
| 6-1.6b | JVET-L0395: 4-pt and 8-pt DST-4 and DCT-4 replacing DST-7 and DCT-8 used in MTS | H. Egilmez (Qualcomm) | Y. Lin (HiSilicon) |
| 6-1.6c | JVET-L0395: 4-pt, 8-pt and 16-pt DST-4 and DCT-4 replacing DST-7 and DCT-8 used in MTS | H. Egilmez (Qualcomm) | Y. Lin (HiSilicon) |

For CTC:

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra** | | | | | **Random Access** | | | | | **Low Delay B** | | | | |
| **Test #** | **Doc. #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CE6-1.1a | JVET-M0496 | -0.17% | -0.14% | -0.11% | 101% | 99% | -0.06% | 0.05% | 0.04% | 101% | 99% | 0.02% | 0.30% | 0.13% | 100% | 98% |
| CE6-1.1b | JVET-M0496 | -0.10% | -0.17% | -0.18% | 102% | 99% | -0.01% | 0.14% | 0.05% | 100% | 100% | 0.05% | 0.00% | 0.01% | 100% | 97% |
| CE6-1.1c | JVET-M0496 | -0.03% | -0.09% | -0.09% | 101% | 100% | 0.07% | 0.12% | 0.11% | 101% | 100% | 0.15% | 0.20% | -0.42% | 99% | 98% |
| CE6-1.1d | JVET-M0496 | -0.04% | -0.11% | -0.13% | 96% | 91% | 0.06% | 0.08% | 0.04% | 99% | 99% | 0.10% | 0.27% | -0.05% | 100% | 100% |
| CE6-1.1e | JVET-M0084 | 0.23% | 0.03% | 0.07% | 103% | 98% | 0.16% | 0.30% | 0.26% | 101% | 101% | 0.04% | 0.22% | -0.17% | 101% | 100% |
| CE6-1.2a | JVET-M0200 | -0.06% | -0.14% | -0.12% | 101% | 99% | 0.07% | 0.14% | 0.11% | 99% | 99% | 0.17% | 0.32% | 0.18% | 97% | 95% |
| CE6-1.3a | JVET-M0244 | 0.08% | 0.11% | 0.10% | 98% | 97% | 0.07% | 0.25% | 0.19% | 100% | 99% | -0.02% | 0.32% | 0.33% | 100% | 101% |
| CE6-1.3b | JVET-M0244 | 0.22% | 0.34% | 0.32% | 97% | 93% | 0.17% | 0.39% | 0.36% | 99% | 99% | 0.03% | 0.34% | 0.10% | 100% | 101% |
| CE6-1.4a | JVET-M0538 | 0.00% | 0.07% | 0.05% | 98% | 94% | -0.01% | 0.08% | 0.13% | 100% | 99% | -0.02% | 0.09% | 0.11% | 99% | 99% |
| CE6-1.4b | JVET-M0538 | -0.07% | 0.01% | 0.00% | 98% | 94% | -0.12% | -0.12% | -0.22% | 100% | 98% | 0.01% | 0.28% | 0.01% | 99% | 97% |
| CE6-1.4c | JVET-M0538 | 0.12% | 0.17% | 0.15% | 95% | 91% | 0.04% | 0.09% | 0.18% | 99% | 99% | 0.04% | 0.20% | 0.19% | 99% | 100% |
| CE6-1.4d | JVET-M0538 | 0.05% | 0.09% | 0.08% | 95% | 90% | -0.06% | -0.11% | -0.14% | 99% | 98% | 0.01% | -0.03% | 0.01% | 98% | 96% |
| CE6-1.5a | JVET-M0080 | 0.07% | 0.06% | 0.06% | 96% | 88% | 0.06% | 0.11% | 0.11% | 99% | 99% | 0.03% | 0.18% | 0.16% | 100% | 100% |
| CE6-1.5b | JVET-M0080 | 0.02% | -0.03% | -0.02% | 98% | 88% | -0.03% | -0.14% | -0.12% | 101% | 99% | -0.01% | 0.04% | -0.15% | 101% | 100% |
| CE6-1.5c | JVET-M0080 | 0.15% | 0.09% | 0.09% | 94% | 85% | 0.09% | 0.19% | 0.25% | 99% | 98% | 0.06% | 0.16% | 0.14% | 100% | 100% |
| CE6-1.5d | JVET-M0080 | 0.09% | 0.01% | 0.02% | 96% | 85% | 0.01% | -0.07% | -0.07% | 101% | 98% | 0.07% | 0.04% | 0.05% | 101% | 100% |
| CE6-1.6a | JVET-M0521 | -0.17% | -0.14% | -0.11% | 99% | 103% | -0.06% | 0.05% | 0.04% | 100% | 101% | 0.02% | 0.30% | 0.13% | 100% | 99% |
| CE6-1.6b | JVET-M0521 | -0.12% | -0.18% | -0.16% | 99% | 101% | -0.02% | 0.16% | 0.02% | 100% | 100% | 0.02% | 0.11% | -0.07% | 100% | 100% |
| CE6-1.6c | JVET-M0521 | 0.08% | -0.06% | -0.04% | 101% | 101% | 0.09% | 0.14% | 0.18% | 100% | 100% | 0.07% | 0.00% | 0.18% | 100% | 100% |

For low QP

The following table summarizes the results for CE6-1 using low QP configuration and VTM-3.0 as anchor.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra** | | | | | **Random Access** | | | | | **Low Delay B** | | | | |
| **Test #** | **Doc. #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CE6-1.1a | JVET-M0496 | 0.00% | -0.06% | -0.06% | 99% | 100% | 0.00% | -0.02% | -0.01% | 100% | 100% | -0.01% | 0.00% | -0.01% | 101% | 101% |
| CE6-1.1b | JVET-M0496 | 0.24% | 0.00% | 0.01% | 101% | 101% | 0.06% | -0.03% | -0.01% | 100% | 101% | 0.02% | -0.01% | 0.00% | 100% | 101% |
| CE6-1.1c | JVET-M0496 | 0.26% | 0.03% | 0.04% | 102% | 101% | 0.12% | 0.04% | 0.06% | 100% | 101% | 0.05% | 0.06% | 0.07% | 99% | 101% |
| CE6-1.1d | JVET-M0496 | 0.28% | 0.04% | 0.04% | 99% | 100% | 0.13% | 0.05% | 0.06% | 100% | 100% | 0.05% | 0.08% | 0.06% | 100% | 102% |
| CE6-1.1e | JVET-M0084 | 0.41% | 0.20% | 0.20% | 101% | 101% | 0.11% | 0.05% | 0.08% | 100% | 100% | 0.04% | 0.03% | 0.03% | 100% | 100% |
| CE6-1.2a | JVET-M0200 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CE6-1.3a | JVET-M0244 | 0.20% | 0.17% | 0.18% | 99% | 100% |  |  |  |  |  |  |  |  |  |  |
| CE6-1.3b | JVET-M0244 | 0.21% | 0.18% | 0.18% | 99% | 99% |  |  |  |  |  |  |  |  |  |  |
| CE6-1.4a | JVET-M0538 | 0.03% | 0.04% | 0.05% | 87% | 101% | 0.01% | 0.04% | 0.04% | 95% | 104% | 0.00% | 0.01% | 0.01% | 91% | 102% |
| CE6-1.4b | JVET-M0538 | 0.03% | 0.04% | 0.05% | 87% | 102% | 0.01% | 0.04% | 0.05% | 95% | 105% | 0.00% | 0.01% | 0.01% | 91% | 101% |
| CE6-1.4c | JVET-M0538 | 0.13% | 0.18% | 0.18% | 85% | 100% | 0.05% | 0.09% | 0.10% | 94% | 103% | 0.02% | 0.05% | 0.04% | 90% | 101% |
| CE6-1.4d | JVET-M0538 | 0.13% | 0.18% | 0.18% | 85% | 101% | 0.05% | 0.09% | 0.09% | 95% | 104% | 0.02% | 0.04% | 0.03% | 90% | 101% |
| CE6-1.5a | JVET-M0080 | 0.05% | 0.07% | 0.07% | 98% | 100% | 0.02% | 0.08% | 0.07% | 99% | 100% |  |  |  |  |  |
| CE6-1.5b | JVET-M0080 | 0.05% | 0.07% | 0.07% | 99% | 100% | 0.02% | 0.07% | 0.06% | 100% | 100% |  |  |  |  |  |
| CE6-1.5c | JVET-M0080 | 0.23% | 0.28% | 0.28% | 96% | 100% | 0.10% | 0.16% | 0.19% | 99% | 100% |  |  |  |  |  |
| CE6-1.5d | JVET-M0080 | 0.23% | 0.28% | 0.28% | 97% | 100% | 0.10% | 0.16% | 0.19% | 99% | 100% |  |  |  |  |  |
| CE6-1.6a | JVET-M0521 | 0.00% | -0.06% | -0.06% | 94% | 97% | 0.00% | -0.02% | -0.01% | 99% | 105% | -0.01% | 0.00% | -0.01% | 96% | 102% |
| CE6-1.6b | JVET-M0521 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CE6-1.6c | JVET-M0521 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

* Coding efficiency
  + Replacing 4-pt DST-7/DCT-8 by DST-4/DCT4
    - CE6-1.1a/b, CE6-1.6a/b/c
  + Enabling 64-length MTS
    - CE6-1.4 b/d
    - CE6-1.5 b/d
* Simplification
  + Memory reduction
    - CE6-1.1 c/e
    - CE6-1.2 a
    - CE6-1.3 a/b
    - CE6-1.4 a/c, CE6-1.5 a/c
  + Complexity (operation) reduction
    - CE6-1.1 d
    - CE6-1.3 b
    - CE6-1.4 a/c, CE6-1.5a/c

Variant 1.6c tried also replacing the 8-pt and 16-pt in addition to the 4-pt and showed worse performance than the anchor. Variants 1.1b and 1.6b tried also replacing the 8-pt in addition to the 4-pt and did not perform as well as only replacing the 4-pt. It was suggested to focus on the “a” variants of 1.1 and 1.6.

Variants 1.1a and 1.6a are actually the same as each other, only replacing the 4-pt DST-7/DCT-8 by DST-4/DCT4; there is a little gain, but it is small (0.06% in RA, 0.17% in AI, mostly for lower resolutions). It was commented that introducing a design inconsistency was undesirable. It was remarked that the DST-4 and DCT4 are subsets of the 8-point DCT2, which could save some memory (16 bytes) if implemented to take advantage of that. In terms of the amount of computation, there is no difference – it’s just a matter of what numbers are used in a matrix multiply.

A complexity reduction proposal, 1.1e, proposes replacing *all* sizes (8, 16, and 32 as well as 4). It has a loss of 0.23% for AI, 0.16% for RA (more loss on class A: 0.6% for AI and 0.2-0.3% for RA). Its complexity benefit is reducing storage for the smaller block sizes since the matrix elements for the DST4 and DCT4 of smaller block sizes become subsets of those of larger block sizes of a DCT2. The implementation is a matrix multiply, so it does not affect cycle counts. The loss for that was considered excessive.

In Track A, it was initially planned to adopt 1.1a/1.6a, pending review of other things in CE6. It was later agreed in the plenary on Sunday 13 January not to take this action (see the notes in section 11.1).

[Copy in the short descriptions]

For considering 64-point transform, two basic approaches, 6-1.4 and 6-1.5, are proposed. For the decoder, to approximate an inverse DST7/DCT8:

* 6-1.4 uses an 8x8 “adjustment” transformation followed by a clipping and an inverse DCT2
* 6-1.5 use a forward DCT2 followed by a sparse matrix

For each of these, four sub-variants are tested:

1. The scheme is applied for 32 length (and MTS is not used for 64-length)
2. The scheme is applied for 32 and 64 lengths
3. The scheme is applied for 16 length and 32 length (and MTS is not used for 64-length)
4. The scheme is applied for 16, 32, and 64 lengths.

The number computations for the worst was reported to be cut approximately in half by 6-1.4 for the cases where the scheme is applied. In the VTM, the worst case is reportedly the length-32 MTS transform.

A participant commented that these increase the number of sequential stages in a way that is undesirable for latency (esp. in hardware). Another participant said it should be possible to “hide” the extra latency for 6-1.4 in the decoder but maybe not for 6-1.5. On the other hand, encoding latency may more of an issue for 6-1.4 (in hardware). It was asked to allow some time for study to consider that issue.

A participant commented that applying this technique to 16 length is not necessary because 32-length DCT2 also needs to be supported and a subset of the 32 point logic that can be used for the 16 point transform (at least for hardware – perhaps there could be an average benefit for software). Based on this understanding, it was suggested to focus on the “a” and “b” variants.

For the CTC, the “a” variant had roughly no effect on coding efficiency, but a little bit of loss was measured in the low QP case (although the loss is very small ~0.05%). In the discussion it was commented that there is some problem in the software that can cause prohibited “zero-out” coefficient positions to be coded (although very rarely – just once for an entire test sequence). A contributor commented that the loss was not observed if RDOQ is disabled.

A participant said that on some well-known sequences (SteamLocomotive and Nebuta) losses up to 1% were observed at ordinary QP values when the 16 point transform was done using this scheme.

For the “b” variants in CTC testing, 6-1.4b showed a little bit of gain (CTC: 0.1% for AI , 0.1% for RA 0.0% for LB) from enabling the longer transform, but 6-1.5b basically did not (on average). A proponent suggested to focus on class A, which is where a longer transform would seem to be more helpful (0.2% for AI , 0.2% for RA).

After discussion, it was discovered that “6-1.4” was some new proposal that was not really part of the CE. That specific scheme had not been documented in the CE plan. It was expressed that the latency issue would need significant time for detailed study.

For schemes targeting memory reduction, up to about 2.7 kbytes of ROM were reported to potentially be saved by each of the following schemes.

* CE6-1.1 c/e (previously discussed)
* CE6-1.2 a
* CE6-1.3 a/b
* CE6-1.4 a/c (non-CE)
* CE6-1.5 a/c

Except for CE6-1.5, these change the DCT2 so it is not quite a DCT2 anymore.

A loss for low QP in the range of 0.2-0.4% was reported for most of these – not for 6-1.5.

It was commented that implementations might not really have as much ROM savings is appears to be possible, and that the ability to reuse HEVC logic is a nice property of the current VTM.

CE6-1.5 had a cascading of stages (discussed above) that seemed to have a latency issue.

No action was taken after considering these issues.

Next category is fast transforms for DST7/DST8 (DCT is not proposed to be modified).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CE6.2: Fast transform** | | | | |
| **Test #** | **Docs** | **Description** | **Tester** | **Cross-checker** |
| 6-2.1a | JVET-M0288 | Fast DST-7/DCT-8 based on DFT  Simplification of transform kernel coefficients, intermediate variables, operations, etc.  Implementation-friendly architecture based on regular matrix multiply | M. Koo (LGE) | P. Philippe (Orange, bcom) |
| 6-2.2a | JVET-M0372 | JVET-L0421: Fast DST-7/DCT-8 based on DFT and matrix multiplication | K. Naser (Technicolor) | H. Gao (Huawei) |
| 6-2.3a | JVET-M0497 | JVET-L0286: Fast DST-7/DCT-8 with dual implementation support | X. Zhao (Tencent) | K. Choi (Samsung) |
| 6-1.4a | JVET-M0538 | See above description |  |  |
| 6-1.4c | See above description |  |  |
| 6-1.5a | JVET-M0080 | See above description |  |  |
| 6-1.5c | See above description |  |  |

The following table summarizes the results for CE6-2 using CTC configuration and VTM-3.0 as anchor.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **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-M0288 | 0.00% | 0.02% | 0.00% | 96% | 90% | -0.01% | 0.01% | 0.07% | 99% | 98% | 0.02% | 0.26% | -0.06% | 100% | 99% |
| CE6-2.2a | JVET-M0372 | 0.08% | 0.05% | 0.04% | 118% | 112% | 0.01% | 0.07% | 0.12% | 116% | 105% | 0.04% | 0.22% | -0.17% | 101% | 100% |
| CE6-2.3a | JVET-M0497 | 0.01% | -0.01% | 0.01% | 96% | 91% | -0.01% | -0.03% | -0.02% | 100% | 100% | 0.00% | 0.22% | -0.22% | 99% | 101% |

The following table summarizes the results for CE6-2 using low QP configuration and VTM-3.0 as anchor.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **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-M0288 | 0.08% | 0.08% | 0.09% | 98% | 99% |  |  |  |  |  |  |  |  |  |  |
| CE6-2.2a | JVET-M0372 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CE6-2.3a | JVET-M0497 | 0.02% | 0.00% | 0.00% | 98% | 99% | 0.01% | 0.00% | 0.01% | 99% | 99% | 0.00% | -0.01% | 0.00% | 100% | 100% |

The following table summarizes the results for CE6-2 using CTC w/ Inter MTS configuration and VTM-3.0 as anchor.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **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-M0288 | 0.00% | 0.02% | 0.00% | 96% | 90% | -0.01% | -0.03% | 0.03% | 97% | 98% | 0.01% | 0.11% | -0.19% | 97% | 96% |
| CE6-2.2a | JVET-M0372 | 0.08% | 0.05% | 0.04% | 118% | 112% | 0.03% | 0.00% | 0.12% |  |  | 0.07% | 0.13% | -0.18% |  |  |
| CE6-2.3a | JVET-M0497 | 0.01% | -0.01% | 0.01% | 96% | 91% | 0.00% | -0.04% | -0.04% | 98% | 100% | 0.00% | 0.18% | -0.37% | 97% | 97% |

Some test results were missing.

The reported runtimes were said to not reflect true differences in complexity; rather, they just reflect implementation-specific code optimizations.

6-2.1a and 6-2.2a were said to be very similar.

6-2.3a had identical results with a matrix multiply. It also had no significant penalty in coding efficiency.

A participant remarked that if a scheme requires cascading multiple stages to get the correct result, this would be undesirable, since the fastest implementation in hardware may typically use parallel-processing matrix multiply.

The 6-2.3a scheme would not provide a benefit for some implementations, but would not be worse to implement in any implementations, and would be desirable for some implementations.

From a spec perspective, 6-2.3a is just changing the value of some numbers in the spec by +/-1.

Decision (complexity reduction): Adopt CE6-2.3a.

In the plenary discussion of Sunday 13 January, it was noted that in the AI configuration, this provides a reported 9% speed-up for the decoder, 4% for the encoder (as tested) – see section 11.1.

Then MTS signalling and selection

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CE6.3: Transform signaling** | | | | |
| **Test #** | **Docs** | **Description** | **Tester** | **Cross-checker** |
| 6-3.1a | JVET-M0303 | Shape adaptive transform selection (up to 32-point DST-7) | J. Lainema (Nokia) | H. Egilmez (Qualcomm) |
| 6-3.1b | Shape adaptive transform selection (up to 16-point DST-7) | J. Lainema (Nokia) | H. Egilmez (Qualcomm) |
| 6-3.2a | JVET-M0522 | Applying MTS to smaller side in case of Nx64 and 64xN) for N < 64, where max. MTS size is set to 32 by default | H. Egilmez (Qualcomm) | J. Lainema (Nokia) |
| 6-3.2b | Applying MTS for MxN in a way that DCT2 is used for M, N > 16, and MTS is applied for M, N <= 16 | H. Egilmez (Qualcomm) | X. Zhao (Tencent) |
| 6-3.2c | MTS with max. MTS size is set to 16 | H. Egilmez (Qualcomm) | J. Lainema (Nokia) |
| 6-3.3a | JVET-M0319 | For 64xN and Nx64 luma transform blocks (N < 64), MTS can be applied to the shorter side. | J. Jung (Wilus) | A. Karabutov (Huawei) |
| 6-3.3b | For 64xN and Nx64 luma transform blocks (N<64), MTS can be applied to the shorter side, with the increased max\_BT and max\_TT sizes for I-slices to 64. | J. Jung (Wilus) | A. Karabutov (Huawei) |
| 6-3.7a | JVET-M0079 | MTS size restriction to 16 | P. Philippe (Orange) | X. Zhao (Tencent) |
| 6-3.8a | JVET-M0498 | Signal horizontal transform if width is less than or equal to 16-point and height is less than or equal to 32, and signal vertical transform if height is less than or equal to 16-point and and width is less than or equal to 32 | J. Jung (Wilus)  X. Zhao (Tencent) | P. Philippe (Orange) |
| 6-3.8b | Signal horizontal transform if width is less than or equal to 16-point and height is less than or equal to 64, and signal vertical transform if height is less than or equal to 16-point and and width is less than or equal to 64 | J. Jung (Wilus)  X. Zhao (Tencent) | P. Philippe (Orange) |

The following table summarizes the results for CE6-3 using CTC configuration and VTM-3.0 as anchor.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra** | | | | | **Random Access** | | | | | **Low Delay B** | | | | |
| **Test #** | **Doc. #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CE6-3.1a | JVET-M0303 | -0.08% | 0.02% | 0.00% | 99% | 102% | -0.03% | 0.01% | 0.07% | 101% | 103% | 0.02% | 0.37% | 0.24% | 100% | 99% |
| CE6-3.1b | JVET-M0303 | -0.06% | -0.02% | -0.08% | 100% | 99% | -0.03% | 0.05% | 0.02% | 100% | 101% | 0.02% | 0.18% | -0.01% | 99% | 99% |
| CE6-3.2a | JVET-M0522 | 0.00% | 0.00% | 0.00% | 99% | 99% | -0.04% | -0.09% | -0.16% | 99% | 98% | 0.02% | -0.02% | 0.10% | 101% | 99% |
| CE6-3.2b | JVET-M0522 | 0.33% | 0.40% | 0.38% | 92% | 93% | 0.18% | 0.39% | 0.48% | 97% | 99% | 0.07% | 0.27% | 0.19% | 99% | 99% |
| CE6-3.2c | JVET-M0522 | 0.55% | 0.62% | 0.63% | 86% | 92% | 0.32% | 0.62% | 0.68% | 95% | 99% | 0.12% | 0.49% | 0.16% | 98% | 99% |
| CE6-3.3a | JVET-M0319 | 0.00% | 0.00% | 0.00% | 100% | 100% | -0.04% | -0.09% | -0.16% | 101% | 100% | 0.02% | -0.02% | 0.10% | 100% | 100% |
| CE6-3.3b | JVET-M0319 | -0.65% | -1.51% | -1.56% | 154% | 100% | -0.18% | -0.66% | -0.71% | 103% | 100% | 0.00% | -0.48% | -0.57% | 101% | 100% |
| CE6-3.7a | JVET-M0079 | 0.55% | 0.62% | 0.63% | 86% | 87% | 0.32% | 0.62% | 0.68% | 95% | 98% | 0.12% | 0.49% | 0.16% | 98% | 99% |
| CE6-3.8a | JVET-M0498 | 0.33% | 0.40% | 0.38% | 91% | 92% | 0.18% | 0.39% | 0.48% | 98% | 99% | 0.07% | 0.27% | 0.19% | 99% | 100% |
| CE6-3.8b | JVET-M0498 | 0.33% | 0.40% | 0.38% | 91% | 93% | 0.17% | 0.29% | 0.43% | 99% | 99% | 0.06% | 0.29% | 0.22% | 99% | 100% |

The following table summarizes the results for CE6-3.1 using CTC w/ MTS = 0 configuration for both test and the VTM-3.0 anchor.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra** | | | | | **Random Access** | | | | | **Low Delay B** | | | | |
| **Test #** | **Doc. #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CE6-3.1a | JVET-M0303 | -1.66% | -2.31% | -2.28% | 99% | 119% | -0.75% | -0.87% | -0.96% | 100% | 108% | -0.09% | -0.18% | -0.33% | 99% | 102% |
| CE6-3.1b | JVET-M0303 | -1.61% | -2.11% | -2.12% | 101% | 111% | -0.71% | -0.81% | -0.84% | 100% | 102% | -0.14% | -0.02% | -0.33% | 100% | 100% |

6-3.1 is motivated by improving coding efficiency (esp. for the case with MTS off). The others in this category are to reduce the maximum MTS transform size (eliminating the 32-point transform).

6-3.1 provides substantial coding gain for when MTS is disabled.

When MTS is disabled or when it is enabled but the low-level MTS flag is 0:

* The CE6-3.1b variant always uses DCT2 when the length of the transform is 32 (or 64).
* The CE6-31.a variant uses 2 transforms of length 32 (but only DCT for length 64).

When the low-level MTS flag is 1, the current 4 combinations are selectable (including for length 32)

Decision: Adopt CE6-3.1b, but with an extra high-level flag to use DCT2 always.

See also the notes of the further discussion of this topic in the plenary of Sunday 13 January in section 11.1.

CE6-3.2b/c, CE6-3.7a, CE6-3.8a/b limit the maximum non-DCT2 transform size to 16. All of these have a loss of more than 0.5% for AI in Class A, which seems unacceptable, so no action was taken on these.

CE6-3.2a, CE6-3.3a/b, use transform type signalling only on one side when one side is length 32 or smaller but the other side 64 long. If both sides are small, signalling is used in both dimensions. The gain for these is approximately negligible (no gain for AI since that case cannot occur, 0.04% in RA when compared to the current MTS, 0.03% benefit in LB when compared to the current MTS) and the encoder runtime is increased by the consideration of these additional cases. So no action was taken on these.

(CE6-3.8a/b also has some usage of signalling for only one direction, but is motivated by trying to eliminate the long non-DCT2 transforms, as discussed above – it has some compression loss.)

CE6-3.3b has gain from two changes: 1) increasing the maximum BT/TT size for I pictures from 32x32 to 64x64, and 2) the signalling scheme from CE6-3.3a. One of these is just an encoder configuration setting. The encoding runtime increased by 54% for AI, with a coding efficiency benefit of 0.65%. The benefit reported for the second modification when using the first modification as an anchor was reportedly 0.08% for AI. Since this affects only a case we chose not to use in CTC and provides only a small benefit, no action was taken on that.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CE6.4: Sub-block transform** | | | | |
| **Test #** | **Docs** | **Description** | **Tester** | **Cross-checker** |
| 6-4.1a | JVET-M0140 | Sub-block Transform (SBT) for inter blocks  - 1-d split (symmetric or 1/4)  - if symmetric, signal which half; others use the 1/4  - transform type of residual TU inferred | Y. Zhao (Huawei) | X. Zhao (Tencent) |
| 6-4.1b | Sub-block Transform (SBT) for inter blocks  - transform type of residual TU always DCT-2 | Y. Zhao (Huawei) | C.-M. Tsai (MediaTek) |
| 6-4.1c | Sub-block Transform (SBT) for inter blocks  - transform type of residual TU signaled (two transform candidates each TU) | Y. Zhao (Huawei) | K. Choi (Samsung) |
| 6-4.1d | Sub-block Transform (SBT) for inter blocks  - transform type of residual TU signaled (four transform candidates each TU, like inter MTS but with more complex context modeling) | Y. Zhao (Huawei) | M. Ikeda (Sony) |
| 6-4.1e | Sub-block Transform (SBT) for inter blocks  - splits of 6-4.1a are allowed, plus  - with Quad-tree split (max TU depth still 1)  - transform type of residual TU inferred | Y. Zhao (Huawei) | X. Zhao (Tencent) |
| 6-4.2a | JVET-M0523 | RQT-like concept of transform sub-block splitting   * One 4-way QT split | Qualcomm | Y. Zhao (Huawei) |
| 6-4.3a | JVET-M0499 | RQT-like concept of transform sub-block splitting   * Square blocks have one 4-way QT split * Rectangular blocks have one long-dimension binary split | X. Zhao (Tencent) | Y. Zhao (Huawei) |
| 6-4.4a | JVET-M0141 | RQT-like concept of transform sub-block splitting   * 4 choices – binary or ternary split (horizontally or vertically) | Y. Zhao (Huawei) | H. Egilmez (Qualcomm) |

Two approaches to sub-block transform:

* Only one sub-block has non-zero coefficients:
  + CE6-4.1a/b/c/d/e
* Each sub-block can have coefficients, with RQT-like scheme
  + CE6-4.2a
  + CE6-4.3a
  + CE6-4.4a

These are all targeting higher coding gain and most are only applicable with inter prediction. Less coding gain is observed when inter-MTS is enabled.

It was suggested to focus on the inter-MTS reference case.

Among the 4.1a/b/c/d/e variations, we would rule out b as not performing so well, and rule out c and d as requiring signalling that doesn’t provide much benefit and adds encoder search complexity and increases decoder support combinations. Variation e is a superset of variation a, adding a 4-way split that provides a small additional gain (0.06% in RA when MTS is enabled).

It was remarked that the length 32 non-DCT2 transform is a problem, and the 4.1a/e schemes are using that transform. It was requested to run a variation where the 32-point DST is not used for 32x64 and 64x32, which are cases not supported in the current VTM and are difficult cases. It was expected that this restriction would have a very small impact. The proponent said they could run a test of that. Revisit for test results on that. [Resolved per notes elsewhere]

The 6-4.4a scheme has 4 choices to make within the sub-block transform mode. The 6-4.2a and 6-4.3a schemes have no choices needed by the encoder and no syntax for such choices.

4.1a/e, 6-4.3a and 6-4.4a are splitting both luma and chroma together, while 6-4.2a is applying the scheme only to luma.

6-4.3a is applying the scheme to intra CUs and the others are not.

Some data was missing for 6-4.3a.

It was commented that 4.1a had been studied quite a bit. It was in a CfP response and has been tested in two CE meeting cycles.

Decision (coding efficiency): Adopt CE6-4.1a (pending the test results of avoiding 32-point DST). The same high-level flag as used for CE6-3.1b is to be used to determine whether DCT2 is used always or not and also applies to CE3-1.1.1.

It was also agreed to not have another CE study of sub-block transform schemes for the next meeting cycle.

The following table summarizes the results for CE6-4 using CTC configuration and VTM-3.0 as anchor.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra** | | | | | **Random Access** | | | | | **Low Delay B** | | | | |
| **Test #** | **Doc. #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CE6-4.1a | JVET-M0140 |  |  |  |  |  | -0.47% | -0.16% | 0.00% | 108% | 101% | -0.83% | -0.98% | -0.06% | 113% | 102% |
| CE6-4.1b | JVET-M0140 |  |  |  |  |  | -0.25% | -0.16% | -0.07% | 107% | 101% | -0.42% | -0.89% | -0.04% | 111% | 101% |
| CE6-4.1c | JVET-M0140 |  |  |  |  |  | -0.54% | -0.20% | 0.08% | 110% | 101% | -0.94% | -0.75% | 0.23% | 116% | 102% |
| CE6-4.1d | JVET-M0140 |  |  |  |  |  | -0.52% | -0.10% | 0.14% | 114% | 101% | -0.90% | -0.70% | 0.25% | 121% | 102% |
| CE6-4.1e | JVET-M0140 |  |  |  |  |  | -0.55% | -0.26% | 0.00% | 109% | 101% | -0.93% | -0.91% | 0.07% | 115% | 102% |
| CE6-4.2a | JVET-M0523 |  |  |  |  |  | -0.36% | 0.09% | 0.35% | 122% | 102% | -0.59% | -0.65% | 0.47% | 129% | 101% |
| CE6-4.2a + InterMTS | JVET-M0523 |  |  |  |  |  | -0.62% | 0.61% | 0.80% | 146% | 105% | -0.94% | 0.68% | 1.41% | 161% | 107% |
| CE6-4.3a | JVET-M0499 | -0.29% | -0.16% | -0.17% | 192.17% | 107% | -0.42% | -0.30% | -0.10% | 143% | 103% | -0.45% | -0.64% | -0.01% | 142% | 104% |
| CE6-4.4a | JVET-M0141 |  |  |  |  |  | -0.59% | -0.35% | 0.10% | 120% | 102% | -1.01% | -1.77% | -0.19% | 127% | 103% |

The following table summarizes the results for CE6-4 using CTC w/ Inter MTS configuration and VTM-3.0 as anchor.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra** | | | | | **Random Access** | | | | | **Low Delay B** | | | | |
| **Test #** | **Doc. #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CE6-4.1a | JVET-M0140 |  |  |  |  |  | -0.28% | -0.21% | -0.06% | 98% | 101% | -0.43% | -0.72% | -0.26% | 96% | 100% |
| CE6-4.1b | JVET-M0140 |  |  |  |  |  | -0.12% | -0.15% | -0.06% | 97% | 101% | -0.20% | -0.67% | -0.21% | 95% | 101% |
| CE6-4.1c | JVET-M0140 |  |  |  |  |  | -0.33% | -0.25% | 0.03% | 100% | 100% | -0.53% | -0.88% | -0.28% | 98% | 101% |
| CE6-4.1d | JVET-M0140 |  |  |  |  |  | -0.29% | -0.14% | 0.03% | 103% | 100% | -0.47% | -0.64% | -0.06% | 102% | 100% |
| CE6-4.1e | JVET-M0140 |  |  |  |  |  | -0.34% | -0.23% | -0.06% | 99% | 101% | -0.55% | -0.73% | -0.21% | 97% | 101% |
| CE6-4.2a | JVET-M0523 |  |  |  |  |  | -0.25% | 0.06% | 0.24% | 120% | 103% | -0.40% | -0.23% | 0.31% | 124% | 101% |
| CE6-4.3a | JVET-M0499 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CE6-4.4a | JVET-M0141 |  |  |  |  |  | -0.30% | -0.29% | 0.01% | 107% | 101% | -0.52% | -1.32% | -0.54% | 105% | 102% |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **CE6.5: Secondary transform** | | | | |
| **Test #** | **Docs** | **Description** | **Tester** | **Cross-checker** |
| 6-5.1 | JVET-M0292 | Reduced Secondary Transform (RST)  - Searching best configurations of RST parameters, such as the number of transform kernels, transform set, and matrix dimension.  - RST index signalling optimization | M. Koo (LGE) | P. Philippe (Orange, bcom) |

In JVET-M0292, test results of CE 6-5.1 on reduced secondary transform (RST) are reported. According to the request of the previous 12th JVET meeting, all tests were performed without normative change of MTS signaling, which are described as the following:

1. Test 1: (A),
2. Test 2: (A) + (B),
3. Test 3: (A) + (B) + (C),
4. Test 4: (A) + (B) + (D), where

|  |  |
| --- | --- |
| Feature | Description |
| (A) | 4 transform sets (instead of 35). 2 transforms per set |
| (B) | Secondary transform uses at most maximum 8 multiplications/sample |
| (C) | Secondary transform is disabled for 4x4 TU |
| (D) | 16x48 matrices are employed instead of 16x64 ones |

The transform set is determined from the intra prediction mode, then a syntax flag is sent to select which kernel in that set is to be applied. The “secondary” (inverse) transform is applied first in the decoding process and then the ordinary (inverse) transform is applied.

The following table summarizes the results for CE6-5 using CTC configuration and VTM-3.0 as anchor.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra** | | | | | **Random Access** | | | | | **Low Delay B** | | | | |
| **Test #** | **Doc. #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CE6-5.1  (Test 1) | JVET-M0292 | -1.59% | -2.75% | -3.22% | 128% | 98% | -0.88% | -1.88% | -2.27% | 108% | 100% | -0.24% | -0.83% | -1.19% | 104% | 101% |
| CE6-5.1  (Test 2) | JVET-M0292 | -1.40% | -2.60% | -3.09% | 128% | 97% | -0.76% | -1.83% | -2.25% | 108% | 100% | -0.21% | -0.78% | -0.85% | 104% | 98% |
| CE6-5.1  (Test 3) | JVET-M0292 | -1.25% | -2.48% | -2.88% | 125% | 97% | -0.69% | -1.59% | -2.03% | 107% | 100% | -0.18% | -0.68% | -1.11% | 103% | 100% |
| CE6-5.1  (Test 4) | JVET-M0292 | -1.34% | -2.50% | -2.95% | 129% | 97% | -0.71% | -1.60% | -2.02% | 107% | 100% | -0.18% | -0.35% | -1.00% | 104% | 99% |

The following table summarizes the results for CE6-5 using CTC w/ Inter MTS configuration and VTM-3.0 as anchor.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra** | | | | | **Random Access** | | | | | **Low Delay B** | | | | |
| **Test #** | **Doc. #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CE6-5.1  (Test 1) | JVET-M0292 |  |  |  |  |  | -0.91% | -1.94% | -2.34% | 106% | 100% | -0.29% | -0.84% | -1.37% | 103% | 100% |
| CE6-5.1  (Test 2) | JVET-M0292 |  |  |  |  |  | -0.80% | -1.89% | -2.27% | 106% | 99% | -0.24% | -0.66% | -1.21% | 103% | 98% |
| CE6-5.1  (Test 3) | JVET-M0292 |  |  |  |  |  | -0.74% | -1.61% | -2.03% | 105% | 99% | -0.22% | -0.64% | -1.21% | 102% | 100% |
| CE6-5.1  (Test 4) | JVET-M0292 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

A cross-checker said the gains are about the same regardless of the test sequence class. Chroma gain as well as luma gain was observed.

The scheme is only applied to intra.

Encoder complexity is increased due to checking both selectable transforms.

It was commented that the encoder runtime tradeoff looks reasonable.

This has some table storage requirement (about 10 kbytes) and a multi-stage latency (but not in the critical path of latency).

The A and B aspects had been tested before.

It was commented that the CE plan did not describe a specific scheme to be tested – a substantial amount of specific design aspects and details were not in the description (the values to be used in the matrices and other aspects).

At the previous meeting it had been suggested to

* Reduce the table size (5 kbytes and 10 kbytes had previously been proposed, where the 5 kbyte scheme had only one candidate secondary transform in each “set” rather than two to choose from); the current proposal has 10 kbytes or with variant D has 7.6 kbytes.
* Reduce the number samples to process with the secondary transform – e.g., applying the secondary transform to only a minimally small subset of the coefficients of the primary transform. In the tested scheme the maximum input vector size is 16 coefficients.

It was remarked that since other changes to the transform have been made, there could be interactions.

It was also remarked that the AI encoding runtime impact is high ~28% and other encoding runtime increases have been adopted, so this could result in an excessive speed impact.

This was further discussed 1545 in Track A on Thursday 17 Jan.The M0292 document had been updated to include more details and spec text. Further study in a CE was requested.

[JVET-M0079](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4882) CE6: MTS size restriction to 16 (test 3.7) [P. Philippe (bcom Orange)]

[JVET-M0080](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4883) CE6: MTS simplification with TAF (tests 1.5a-d) [P. Philippe (bcom Orange)]

[JVET-M0084](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4887) CE6: JVET-L0262: Replacing all DST-7 / DCT-8 by DST-4 / DCT-4 used in MTS (test 6.1.1e) [K. Abe, T. Toma (Panasonic), M. Ikeda, T. Tsukuba (Sony), K. Naser, F. Le Léannec, E. François (Technicolor)]

[JVET-M0140](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4947) CE6: Sub-block transform for inter blocks (Test 6.4.1) [Y. Zhao, H. Gao, H. Yang, J. Chen (Huawei)]

[JVET-M0141](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4948) CE6: RQT-like sub-block transform for inter blocks (Test 6.4.4) [Y. Zhao, H. Gao, H. Yang, J. Chen (Huawei)]

[JVET-M0200](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5007) CE6: Unified matrix for transform (Test 6-1.2a) [K. Choi, M. Park, M. W. Park, W. Choi (Samsung)]

[JVET-M0244](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5051) CE6: MTS using DST-4 and transposed DCT-2 (test 6-1.3) [Y. Lin, J. Zheng, Q. Yu, N. Zhang (HiSilicon), C. Zhu (UESTC)]

[JVET-M0288](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5095) CE6-2.1: Fast DST-7/DCT-8 based on DFT [M. Koo, M. Salehifar, J. Lim, S. Kim (LGE)]

[JVET-M0292](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5099) CE6-5.1: Reduced Secondary Transform (RST) [M. Koo, M. Salehifar, J. Lim, S. Kim (LGE)]

[JVET-M0303](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5110) CE6: Shape adaptive transform selection (Test 3.1) [J. Lainema (Nokia)]

[JVET-M0319](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5126) CE6: MTS for non-square CUs (test 6.3.3) [J. Jung, D. Kim, G. Ko, J. Son, J. Kwak (WILUS)]

[JVET-M0372](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5179) CE6-2.2: Fast DST-7/DCT-8 based on DFT and matrix multiplication [K. Naser, E. François, F. Le Léannec (Technicolor)]

[JVET-M0496](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5306) CE6: Compound Orthonormal Transform (Test 6.1.1 a/b/c/d) [X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-M0497](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5307) CE6: Fast DST-7/DCT-8 with dual implementation support (Test 6.2.3) [X. Zhao, X. Li, Y. Luo, S. Liu (Tencent)]

[JVET-M0498](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5308) CE6: MTS up to 16-length (Test 6.3.8) [J. Jung, D. Kim, G. Ko, J.-H. Son, J. S. Kwak (Wilus), X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-M0499](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5309) CE6: RQT-like transform sub-block splitting (Test 6.4.3) [X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-M0521](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5332) CE6: Replacement of 4-point DST7/DCT8 with DST4/DCT4 in MTS (Test 6.1.6) [H. Egilmez, V. Seregin, A. Said, T. Hsieh, M. Karczewicz (Qualcomm)]

[JVET-M0522](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5333) CE6: MTS support for large rectangular blocks (Test 6.3.2) [H. Egilmez, V. Seregin, A. Said, M. Karczewicz (Qualcomm)]

[JVET-M0523](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5334) CE6: RQT-like transform partitioning for inter blocks (Test 6.4.2) [H. Egilmez, V. Seregin, A. Said, M. Karczewicz (Qualcomm)]

## CE7: Quantization and coefficient coding (2)

Contributions in this category were discussed Saturday 12 Jan. 1500–XXXX (chaired by GJS).

[JVET-M0027](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4844) 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 4 tests on transform coefficient coding.

The purpose of this core experiment is to explore the coding efficiency and complexity impact of proposed algorithms for quantization and transform coefficient coding. This core experiment evaluates the impact of:

Context modeling/selection/coding order for syntax elements related to transform coefficients

The objectives of this CE include:

Investigation of the impact of context selection and signaling schemes for transform coefficient levels on the coding efficiency and complexity.

**Transform coefficient coding**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Tester** | **Tool** | **Cross checker** |
| 7.1 | Tzu-Der Chuang (MediaTek) | [1] Constraints on the number of context-coded bins depend on whether luma or chroma is coded (and, for chroma, on the subblock size) | Yu-Chen Sun (Alibaba) |
| 7.2 | Tzu-Der Chuang (MediaTek) | [1] Constraints on the number of context-coded bins depend on whether luma or chroma is coded (and, for chroma, on the subblock size) + [2] Constraints on the number of context-coded bins depend on last significant scan position | Jung-Ah Choi (LGE) M. Coban (Qualcomm) |
| 7.3 | Tzu-Der Chuang (MediaTek) | [1] Constraints on the number of context-coded bins depend on whether luma or chroma is coded (and, for chroma, on the subblock size) + [2] Constraints on the number of context-coded bins depend on last significant scan position + [3] Include rem\_abs\_gt2\_flag into first coding pass | H. Schwarz (HHI) M. Coban (Qualcomm) |
| 7.4 | Tzu-Der Chuang (MediaTek) | [3] Include rem\_abs\_gt2\_flag into first coding pass | H. Schwarz (HHI) |

In JVET-L0145, three methods to constrain the usage of context-coded bins are proposed. The first constraint is dependent on color component and coefficient sub-block size. The second method is to release the constraints values according to the last significant sub-block position to improve the coding efficiency. The third modification is to move the greater than 2 flag into the first pass to further improve the decoding throughput. The details are described as follow.

**[1] Different constraints according to colour components and sub-block sizes**

The number of context-coded bins (including greater than 2 flag) constraints are set to 30 on 4x4 luma subblocks, 16 on 4x4 chroma subblocks, and 4 on 2x2 chroma subblocks, respectively. The number of context-coded bin constraints on greater than 2 are set to 4 on 4x4 luma subblocks, 2 on 4x4 chroma subblocks, and 1 on 2x2 chroma sub-blocks, respectively.

**[2] Last significant subblock position dependent constraint**

According to the last significant subblock position, the number of to-be-coded sub-blocks in a TB can be derived. The constraint value is determined according to the color component and the coefficient sub-block size. With the number of to-be-coded sub-blocks (NumToBeCodedSb) and the number of total coefficient sub-blocks in a TB (NumTotalSb), the constraint value (ConstraintValue) is modified as follows.

(if (NumToBeCodedSb \* 2 <= NumTotalSb)

( (ConstraintValue = ConstraintValue \* 2;

(else if (NumToBeCodedSb \* 5 <= NumTotalSb \* 4)

( (ConstraintValue = (ConstraintValue \* 5) >> 2;

**[3] Include greater than 2 flag into the first coding pass**

The greater than 2 flag is proposed to be moved to the first coding pass after the parity bit. The parsed greater than 2 flag is used to calculate the locSumAbsPass1in the context modeling of sig\_coeff\_flag, par\_level\_flag, rem\_abs\_gt1\_flag, and rem\_abs\_gt2\_flag. The reserved number of context-coded bins for greater than 2 flag in the second coding pass is also merged into the number of context-coded bins for the first coding pass. The test that moving the greater than 2 flag before parity bit will also be evaluated.

**Specification of tests:**

Test 7.1: Aspect [1] ( (To reduce worst-case context coded bins (2 per coeff to ~1.6)

Test 7.2: Aspects [1] + [2] ( (Improving coding efficiency relative to 7.1

Test 7.3: Aspects [1] + [2] + [3] (Reduces the scan passes relative to 7.2

Test 7.4: Aspect [3] ( (Reduces the scan passes without including other changes

Average test results for CE 7. The table shows results for a high-complexity encoder configurations (same as CTC) as well as a low-complexity encoder configuration (dependent quantization and RDOQ disabled). All results are relative to VTM-3.0 (using the same configuration as the tested approach).

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **CE 7** | | **High complexity (CTC)** | | | | | **Low complexity (DQ off, RDOQ off)** | | | | |
| Y | U | V | encT | decT | Y | U | V | encT | decT |
| **AI** | 7.1 | 0.08% | 0.64% | 0.44% | 102% | 101% | 0.12% | 0.42% | 0.47% | 100% | 101% |
| 7.2 | 0.06% | 0.19% | 0.10% | 104% | 102% | 0.06% | 0.12% | 0.14% | 100% | 102% |
| 7.3 | 0.00% | 0.09% | 0.05% | 103% | 101% | 0.00% | 0.03% | 0.11% | 99% | 101% |
| 7.4 | -0.08% | -0.09% | -0.10% | 100% | 101% | -0.05% | -0.08% | -0.08% | 99% | 101% |
| **RA** | 7.1 | 0.07% | 0.87% | 0.69% | 101% | 100% | 0.09% | 0.45% | 0.58% | 100% | 102% |
| 7.2 | 0.03% | 0.35% | 0.30% | 101% | 101% | 0.03% | 0.15% | 0.22% | 100% | 102% |
| 7.3 | 0.00% | 0.30% | 0.23% | 101% | 102% | 0.02% | 0.14% | 0.17% | 100% | 102% |
| 7.4 | -0.06% | 0.03% | -0.06% | 100% | 100% | -0.02% | -0.12% | -0.02% | 100% | 102% |
| **LB** | 7.1 | 0.09% | 1.58% | 0.89% | 101% | 102% | -0.02% | 1.03% | 0.66% | 100% | 100% |
| 7.2 | 0.00% | 0.57% | 0.14% | 102% | 101% | -0.01% | 0.40% | 0.13% | 100% | 99% |
| 7.3 | 0.02% | 0.58% | -0.12% | 101% | 100% | -0.01% | 0.50% | 0.09% | 100% | 99% |
| 7.4 | -0.04% | 0.00% | 0.12% | 100% | 100% | 0.02% | -0.15% | -0.09% | 100% | 99% |

For test 7.1, there is clear loss and especially in Class A.

It was asked whether this had been tested with low QPs. It had not.

The current scheme imposes this limit by counting the number of context coded bins in a coefficient group and switching to bypass when a limit is exceeded.

It was commented that limiting the context coded bins at this very low level – the 4x4 level, may not be desirable – that imposing such a limit at a higher level may be better. However, it was commented by others that HEVC has a similar counting and switching requirement.

Aspect number [3] (test CE7.4), which reduces scan passes, was suggested to be “cleaner” and should increase throughput.

Decision (complexity reduction): Adopt CE7.4.

There was interest in further work for reducing the worst-case number of context-coded bins, but the currently tested methods may not be the right approach for that.

A suggestion for the further study was to establish a limit at some higher level rather than on each coefficient group. It was recommended to study the matter of the worst-case number of context-coded bins in an AHG.

[JVET-M0173](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4980) CE7 (Tests 7.1, 7.2, 7.3, and 7.4): 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)]

## CE8: Screen content coding tools (15)

Contributions in this category were discussed Friday 11 Jan. 1120–1330 and 1500-1615 (Track B chaired by JRO).

[JVET-M0028](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5316) CE8: Summary Report on Screen Content Coding [X. Xu, Y.-C. Chao, Y.-C. Sun, J. Xu]

8.1: CPR related

8.2: Palette related

8.3: Block-based DPCM

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Test** | **Tester** | **Document** | **Tool description** | **Cross checker** |
| 8.1.1a | J. Nam  (LGE) | JVET-M0332 | Block vector prediction for merge mode and AMVP mode using default positions. | X. Xu  (Tencent) |
| 8.1.1b | J. Nam  (LGE) | JVET-M0332 | Block vector prediction for merge mode and AMVP mode. Consider alternative candidates with various positions | A. Karabutov  (Huawei) |
| 8.1.2a | X. Xu  (Tencent) | JVET-M0407 | Reference sample memory reuse, update reference sample memory on 64x64 basis, keep the requirement for total memory (4 64x64 blocks) unchanged | A. Karabutov  (Huawei) |
| 8.1.2b | X. Xu  (Tencent) | JVET-M0408 | Reference sample memory reuse, update reference sample memory on 64x64 basis, reduce the requirement for total memory to 3 64x64 blocks | J. Nam  (LGE) |
| 8.1.2c | X. Xu  (Tencent) | JVET-M0408 | Reference sample memory reuse, update reference sample memory on 64x64 basis, reduce the requirement for total memory to 2 64x64 blocks | J. Nam  (LGE) |
| 8.1.2d | X. Xu  (Tencent) | JVET-M0407 | Reference sample memory reuse, update reference sample memory on CU basis, keep the requirement for total memory (4 64x64 blocks) unchanged | A. Karabutov  (Huawei) |
| 8.1.3 | L. P. Van  (Qualcomm) | JVET-M0474 | CPR using extended search range with line buffers from top of CTU and the left columns of the current CTU |  |
| 8.2.1 | Y.-H. Chao  (Qualcomm)  Y.-C. Sun  (Alibaba) | JVET-M0050 | Palette mode as in HEVC SCC, CE base software | R. Chernyak  (Huawei) |
| 8.2.2 | Y.-C. Sun  (Alibaba) | JVET-M0051 | Palette mode and intra mode combination | Y.-W. Chen (Kwai) |
| 8.2.3 | J. Ye  (Tencent) | JVET-M0455 | Palette index map scan order constraints | R. Chernyak  (Huawei) |
| 8.2.4 | J. Ye  (Tencent) | JVET-M0456 | Apply palette mode on separate chroma CU only when corresponding luma samples are all coded in palette mode | Y.-C. Sun (Alibaba) |
| 8.2.5a | R. Chernyak  (Huawei)  Y.-H. Chao  (Qualcomm)  Y.-C. Sun  (Alibaba) | JVET-M0052 | Separate palette coding for luma and chroma  Sub test 1: palette coding is applied separately on luma and chroma components in both intra and inter slices when dual tree is disabled in configuration (SPS) | J. Ye  (Tencent) |
| 8.2.5b | R. Chernyak  (Huawei)  Y.-H. Chao  (Qualcomm)  Y.-C. Sun  (Alibaba) | JVET-M0052 | Separate palette coding for luma and chroma  Sub test 2: palette coding is applied separately on luma and chroma components in both intra and inter slices when dual tree is enabled in configuration (SPS) | J. Ye  (Tencent) |
| 8.2.6 | J. Ye (Tencent) | JVET-M0457 | Palette predictor list enhancement by using palette coded spatial neighbors | Y.-C. Sun (Alibaba) |
| 8.3.1a | F. Henry  (Orange) | JVET-M0056 | BDPCM with throughput reduction, investigating:  - Block size limitation of BDPCM and impact on throughput  - Independently decodable regions inside BDPCM block (in a manner similar to RDPCM throughput reduction proposed in JCT-VC M0439 [16]) and impact on throughput | B. Bross (HHI) |
| 8.3.1b | F. Henry  (Orange) | JVET-M0057 | Same as 8.3.1a with vertical and horizontal predictors (in a way similar to RDPCM), allowing the reconstruction to proceed line by line / column by column and thus increase throughput | B. Bross (HHI) |
| 8.3.2 | F. Henry  (Orange) | JVET-M0058 | BDPCM bin/context reduction  - Use different approaches to encode the BDPCM residual in order to reduce the number of bins and associated contexts | B. Bross (HHI) |

Results compared to CTC (without CPR), all CE results have CPR enabled

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **AI Over VTM-3.0** | | | | | **RA Over VTM-3.0** | | | | |
|  | **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CTC overall | VTM+CPR | -0.27% | -0.40% | -0.33% | 137% | 100% | 0.09% | -0.01% | 0.05% | 100% | 100% |
| CE8.1.1a | -0.34% | -0.43% | -0.41% | 144% | 104% | 0.05% | -0.06% | 0.00% | 101% | 101% |
| CE8.1.1b | -0.34% | -0.41% | -0.37% | 144% | 104% | 0.05% | 0.00% | 0.05% | 101% | 102% |
| CE8.1.2a | -0.35% | -0.46% | -0.42% | 142% | 102% | 0.05% | -0.04% | -0.03% | 100% | 99% |
| CE8.1.2b | -0.31% | -0.41% | -0.35% | 143% | 98% | 0.07% | -0.04% | 0.04% | 99% | 98% |
| CE8.1.2c | -0.22% | -0.30% | -0.30% | 139% | 100% | 0.11% | -0.07% | 0.08% | 99% | 99% |
| CE8.1.2d | -0.39% | -0.48% | -0.48% | 143% | 99% | 0.05% | 0.01% | 0.02% | 99% | 99% |
| CE8.1.3 | -0.29% | -0.37% | -0.34% | 137% | 103% | 0.08% | 0.01% | 0.02% | 100% | 100% |
| CE8.2.1 | -0.19% | -0.26% | -0.26% | 146% | 105% | 0.20% | 0.07% | 0.20% | 108% | 104% |
| CE8.2.1\* | -0.36% | -0.65% | -0.81% | 142% | 100% | 0.16% | -0.30% | -0.22% | 107% | 102% |
| CE8.2.2 | -0.19% | -0.24% | -0.26% | 147% | 105% | 0.22% | 0.07% | 0.18% | 106% | 103% |
| CE8.2.3 | -0.19% | -0.26% | -0.25% | 142% | 104% | 0.20% | 0.05% | 0.15% | 100% | 99% |
| CE8.2.4 | -0.21% | -0.30% | -0.26% | 141% | 105% | 0.20% | 0.10% | 0.22% | 101% | 99% |
| CE8.2.5a | -0.36% | -0.63% | -0.81% | 142% | 100% | 0.15% | -0.32% | -0.24% | 106% | 101% |
| CE8.2.5b | -0.19% | -0.26% | -0.26% | 146% | 105% | 0.20% | 0.05% | 0.13% | 105% | 103% |
| CE8.2.6 | -0.19% | -0.27% | -0.26% | 143% | 104% | 0.20% | 0.08% | 0.18% | 101% | 100% |
| CE8.3.1a | -0.24% | -0.42% | -0.36% | 134% | 104% | 0.11% | 0.03% | 0.09% | 101% | 102% |
| CE8.3.1b | -0.34% | -0.37% | -0.32% | 137% | 106% | 0.07% | -0.01% | 0.09% | 102% | 102% |
| CE8.3.2 | -0.34% | -0.37% | -0.33% | 137% | 106% | 0.07% | -0.01% | 0.08% | 102% | 102% |
| Class F | VTM+CPR | -12.09% | -12.04% | -12.10% | 158% | 99% | -9.89% | -9.92% | -9.95% | 107% | 99% |
| CE8.1.1a | -12.42% | -12.24% | -12.27% | 161% | 104% | -10.10% | -9.99% | -10.12% | 108% | 102% |
| CE8.1.1b | -12.41% | -12.37% | -12.34% | 162% | 106% | -10.07% | -9.94% | -10.16% | 108% | 102% |
| CE8.1.2a | -14.47% | -14.32% | -14.26% | 175% | 103% | -11.62% | -11.63% | -11.49% | 109% | 98% |
| CE8.1.2b | -13.66% | -13.52% | -13.49% | 172% | 97% | -11.04% | -11.05% | -11.07% | 109% | 97% |
| CE8.1.2c | -12.11% | -12.04% | -11.94% | 164% | 97% | -9.88% | -9.89% | -10.04% | 108% | 98% |
| CE8.1.2d | -15.34% | -15.20% | -15.15% | 178% | 96% | -12.34% | -12.28% | -12.22% | 109% | 97% |
| CE8.1.3 | -12.21% | -12.14% | -12.19% | 159% | 104% | -9.96% | -10.10% | -9.99% | 106% | 101% |
| CE8.2.1 | -15.51% | -14.05% | -14.13% | 174% | 97% | -11.90% | -11.77% | -11.99% | 119% | 103% |
| CE8.2.1\* | -13.16% | -13.63% | -13.62% | 159% | 96% | -10.48% | -11.17% | -11.20% | 118% | 102% |
| CE8.2.2 | -15.53% | -14.03% | -14.11% | 174% | 97% | -11.94% | -11.72% | -11.94% | 119% | 103% |
| CE8.2.3 | -15.50% | -14.03% | -14.09% | 173% | 100% | -11.90% | -11.72% | -11.92% | 110% | 98% |
| CE8.2.4 | -15.62% | -13.29% | -13.31% | 169% | 99% | -12.03% | -11.00% | -11.12% | 110% | 98% |
| CE8.2.5a | -14.59% | -14.28% | -14.61% | 167% | 93% | -11.43% | -11.08% | -11.70% | 118% | 99% |
| CE8.2.5b | -15.51% | -14.05% | -14.13% | 174% | 97% | -11.97% | -11.64% | -11.89% | 118% | 104% |
| CE8.2.6 | -15.49% | -13.98% | -14.09% | 175% | 100% | -11.87% | -11.53% | -11.90% | 110% | 99% |
| CE8.3.1a | -13.09% | -13.59% | -13.60% | 136% | 103% | -10.41% | -10.92% | -10.98% | 109% | 101% |
| CE8.3.1b | -15.75% | -14.12% | -14.14% | 139% | 106% | -12.48% | -11.27% | -11.42% | 111% | 102% |
| CE8.3.2 | -15.68% | -14.05% | -14.06% | 139% | 106% | -12.43% | -11.30% | -11.34% | 110% | 102% |
| SCC 1080p | VTM+CPR | -36.92% | -36.11% | -36.36% | 143% | 90% | -22.03% | -21.58% | -22.10% | 103% | 96% |
| CE8.1.1a | -37.81% | -36.76% | -37.03% | 139% | 102% | -22.77% | -22.27% | -22.78% | 104% | 100% |
| CE8.1.1b | -37.80% | -36.76% | -37.03% | 138% | 101% | -22.69% | -22.18% | -22.73% | 104% | 100% |
| CE8.1.2a | -42.96% | -41.68% | -41.99% | 147% | 90% | -25.89% | -25.17% | -25.82% | 103% | 95% |
| CE8.1.2b | -41.02% | -39.81% | -40.12% | 151% | 86% | -24.55% | -23.96% | -24.54% | 104% | 94% |
| CE8.1.2c | -36.76% | -35.55% | -35.83% | 150% | 89% | -21.43% | -20.80% | -21.35% | 105% | 94% |
| CE8.1.2d | -45.00% | -43.77% | -44.06% | 151% | 85% | -27.25% | -26.61% | -27.20% | 103% | 94% |
| CE8.1.3 | -37.14% | -36.32% | -36.57% | 144% | 97% | -22.17% | -21.75% | -22.27% | 105% | 100% |
| CE8.2.1 | -44.77% | -41.06% | -41.27% | 157% | 75% | -25.67% | -24.47% | -24.82% | 110% | 96% |
| CE8.2.1\* | -39.08% | -38.45% | -38.66% | 149% | 80% | -22.67% | -22.57% | -22.80% | 107% | 93% |
| CE8.2.2 | -45.18% | -41.22% | -41.45% | 155% | 76% | -26.03% | -24.68% | -25.04% | 110% | 95% |
| CE8.2.3 | -44.75% | -41.03% | -41.26% | 156% | 77% | -25.64% | -24.50% | -24.80% | 102% | 90% |
| CE8.2.4 | -44.78% | -41.04% | -41.26% | 158% | 80% | -25.65% | -24.40% | -24.77% | 102% | 91% |
| CE8.2.5a | -41.75% | -40.55% | -40.56% | 157% | 70% | -24.88% | -24.46% | -24.44% | 106% | 91% |
| CE8.2.5b | -44.77% | -41.06% | -41.27% | 157% | 75% | -26.03% | -24.75% | -24.95% | 108% | 95% |
| CE8.2.6 | -44.78% | -41.04% | -41.26% | 158% | 80% | -25.65% | -24.40% | -24.77% | 102% | 91% |
| CE8.3.1a | -38.67% | -38.38% | -38.57% | 104% | 94% | -23.03% | -22.87% | -23.29% | 105% | 98% |
| CE8.3.1b | -42.26% | -39.36% | -39.70% | 107% | 101% | -25.50% | -23.29% | -23.84% | 106% | 99% |
| CE8.3.2 | -41.97% | -39.22% | -39.55% | 107% | 102% | -25.45% | -23.27% | -23.78% | 104% | 99% |

\* PLT mode in HEVC SCC, when dual-tree SPS is off (the baseline version of CE 8.2.1 uses dual tree)

Results compared to CTC (without CPR), all CE results have CPR+PLT enabled

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **AI Over VTM-3.0** | | | | | **RA Over VTM-3.0** | | | | |
|  | **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CTC overall | VTM+CPR+PLT | -0.19% | -0.26% | -0.26% | 145% | 103% | 0.20% | 0.07% | 0.20% | 105% | 102% |
| CE8.1.1a | -0.25% | -0.32% | -0.36% | 151% | 104% | 0.17% | 0.06% | 0.05% | 106% | 102% |
| CE8.1.1b | -0.24% | -0.30% | -0.30% | 151% | 105% | 0.18% | 0.09% | 0.04% | 105% | 101% |
| CE8.1.2a | -0.26% | -0.33% | -0.37% | 149% | 101% | 0.19% | 0.11% | 0.17% | 104% | 99% |
| CE8.1.2b | -0.22% | -0.31% | -0.30% | 152% | 104% | 0.21% | 0.05% | 0.15% | 106% | 102% |
| CE8.1.2c | -0.14% | -0.19% | -0.21% | 150% | 105% | 0.23% | 0.07% | 0.17% | 106% | 102% |
| CE8.1.2d | -0.30% | -0.37% | -0.38% | 152% | 105% | 0.18% | 0.08% | 0.12% | 105% | 102% |
| CE8.1.3 | -0.19% | -0.31% | -0.25% | 144% | 103% | 0.21% | 0.05% | 0.16% | 104% | 100% |
| CE8.2.1 | -0.19% | -0.26% | -0.26% | 146% | 105% | 0.20% | 0.07% | 0.20% | 108% | 104% |
| CE8.2.2 | -0.19% | -0.24% | -0.26% | 147% | 105% | 0.22% | 0.07% | 0.18% | 106% | 103% |
| CE8.2.3 | -0.19% | -0.26% | -0.25% | 142% | 104% | 0.20% | 0.05% | 0.15% | 100% | 99% |
| CE8.2.4 | -0.21% | -0.30% | -0.26% | 141% | 105% | 0.20% | 0.10% | 0.22% | 101% | 99% |
| CE8.2.5a | -0.36% | -0.63% | -0.81% | 142% | 100% | 0.15% | -0.32% | -0.24% | 106% | 101% |
| CE8.2.5b | -0.19% | -0.26% | -0.26% | 146% | 105% | 0.20% | 0.05% | 0.13% | 105% | 103% |
| CE8.2.6 | -0.19% | -0.27% | -0.26% | 143% | 104% | 0.20% | 0.08% | 0.18% | 101% | 100% |
| CE8.3.1a | -0.16% | -0.30% | -0.32% | 170% | 116% | 0.24% | 0.07% | 0.17% | 141% | 122% |
| CE8.3.1b | -0.27% | -0.29% | -0.24% | 141% | 109% | 0.18% | 0.14% | 0.24% | 104% | 105% |
| CE8.3.2 | -0.27% | -0.28% | -0.24% | 141% | 109% | 0.18% | 0.15% | 0.26% | 105% | 106% |
| Class F | VTM+CPR+PLT | -15.51% | -14.05% | -14.13% | 173% | 97% | -11.90% | -11.77% | -11.99% | 115% | 100% |
| CE8.1.1a | -15.61% | -14.25% | -14.33% | 176% | 97% | -12.01% | -11.77% | -12.05% | 116% | 100% |
| CE8.1.1b | -15.62% | -14.18% | -14.25% | 176% | 98% | -12.02% | -11.78% | -11.95% | 116% | 100% |
| CE8.1.2a | -16.95% | -15.79% | -15.92% | 182% | 95% | -13.09% | -13.00% | -13.18% | 115% | 97% |
| CE8.1.2b | -16.44% | -15.15% | -15.25% | 185% | 99% | -12.66% | -12.51% | -12.73% | 118% | 101% |
| CE8.1.2c | -15.29% | -13.87% | -13.97% | 179% | 97% | -11.79% | -11.59% | -11.76% | 117% | 100% |
| CE8.1.2d | -17.71% | -16.58% | -16.68% | 191% | 100% | -13.66% | -13.50% | -13.75% | 118% | 101% |
| CE8.1.3 | -15.57% | -14.12% | -14.27% | 171% | 96% | -12.00% | -11.84% | -12.07% | 112% | 97% |
| CE8.2.1 | -15.51% | -14.05% | -14.13% | 174% | 97% | -11.90% | -11.77% | -11.99% | 119% | 103% |
| CE8.2.2 | -15.53% | -14.03% | -14.11% | 174% | 97% | -11.94% | -11.72% | -11.94% | 119% | 103% |
| CE8.2.3 | -15.50% | -14.03% | -14.09% | 173% | 100% | -11.90% | -11.72% | -11.92% | 110% | 98% |
| CE8.2.4 | -15.62% | -13.29% | -13.31% | 169% | 99% | -12.03% | -11.00% | -11.12% | 110% | 98% |
| CE8.2.5a | -14.59% | -14.28% | -14.61% | 167% | 93% | -11.43% | -11.08% | -11.70% | 118% | 99% |
| CE8.2.5b | -15.51% | -14.05% | -14.13% | 174% | 97% | -11.97% | -11.64% | -11.89% | 118% | 104% |
| CE8.2.6 | -15.49% | -13.98% | -14.09% | 175% | 100% | -11.87% | -11.53% | -11.90% | 110% | 99% |
| CE8.3.1a | -15.81% | -14.80% | -14.98% | 175% | 113% | -12.12% | -11.98% | -12.30% | 147% | 119% |
| CE8.3.1b | -16.81% | -15.47% | -15.63% | 143% | 104% | -12.95% | -12.24% | -12.56% | 113% | 104% |
| CE8.3.2 | -16.80% | -15.44% | -15.62% | 143% | 105% | -12.93% | -12.26% | -12.57% | 114% | 105% |
| SCC 1080p | VTM+CPR+PLT | -44.77% | -41.06% | -41.27% | 158% | 77% | -25.67% | -24.49% | -24.84% | 106% | 93% |
| CE8.1.1a | -45.08% | -41.40% | -41.60% | 155% | 80% | -26.14% | -24.92% | -25.30% | 108% | 95% |
| CE8.1.1b | -45.09% | -41.40% | -41.61% | 155% | 80% | -26.12% | -24.91% | -25.30% | 108% | 95% |
| CE8.1.2a | -48.16% | -44.73% | -44.97% | 156% | 75% | -28.04% | -26.75% | -27.18% | 104% | 91% |
| CE8.1.2b | -46.92% | -43.43% | -43.67% | 164% | 79% | -27.13% | -25.86% | -26.32% | 107% | 94% |
| CE8.1.2c | -43.87% | -40.16% | -40.35% | 164% | 77% | -24.73% | -23.54% | -23.90% | 109% | 94% |
| CE8.1.2d | -49.80% | -46.50% | -46.74% | 159% | 78% | -29.13% | -27.90% | -28.39% | 106% | 93% |
| CE8.1.3 | -44.89% | -41.21% | -41.42% | 157% | 77% | -25.74% | -24.58% | -24.94% | 107% | 95% |
| CE8.2.1 | -44.77% | -41.06% | -41.27% | 157% | 75% | -25.67% | -24.47% | -24.82% | 110% | 96% |
| CE8.2.2 | -45.18% | -41.22% | -41.45% | 155% | 76% | -26.03% | -24.68% | -25.04% | 110% | 95% |
| CE8.2.3 | -44.75% | -41.03% | -41.26% | 156% | 77% | -25.64% | -24.50% | -24.80% | 102% | 90% |
| CE8.2.4 | -45.03% | -40.16% | -40.41% | 158% | 82% | -25.77% | -23.77% | -24.18% | 102% | 91% |
| CE8.2.5a | -41.75% | -40.55% | -40.56% | 157% | 70% | -24.88% | -24.46% | -24.44% | 106% | 91% |
| CE8.2.5b | -44.77% | -41.06% | -41.27% | 157% | 75% | -26.03% | -24.75% | -24.95% | 108% | 95% |
| CE8.2.6 | -44.78% | -41.04% | -41.26% | 158% | 80% | -25.65% | -24.40% | -24.77% | 102% | 91% |
| CE8.3.1a | -45.25% | -42.15% | -42.34% | 130% | 93% | -24.20% | -23.13% | -23.45% | 133% | 111% |
| CE8.3.1b | -46.17% | -42.67% | -42.88% | 106% | 89% | -25.31% | -23.46% | -23.88% | 104% | 102% |
| CE8.3.2 | -46.16% | -42.65% | -42.86% | 106% | 90% | -25.30% | -23.48% | -23.88% | 105% | 99% |

Results compared to CTC (without CPR), all CE results have PLT enabled

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **AI Over VTM-3.0** | | | | | **RA Over VTM-3.0** | | | | |
|  | **Test#** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CTC overall | VTM+PLT | 0.09% | 0.10% | 0.06% | 107% | 101% | 0.14% | 0.20% | 0.09% | 106% | 102% |
| CE8.2.1 | 0.09% | 0.10% | 0.06% | 107% | 101% | 0.14% | 0.20% | 0.09% | 106% | 102% |
| CE8.2.1\* | 0.07% | 0.07% | 0.01% | 108% | 101% | 0.14% | 0.09% | 0.08% | 106% | 101% |
| CE8.2.2 | 0.08% | 0.09% | 0.11% | 108% | 103% | 0.14% | 0.18% | 0.10% | 106% | 102% |
| CE8.2.3 | 0.08% | 0.10% | 0.07% | 106% | 101% | 0.12% | 0.17% | 0.13% | 100% | 98% |
| CE8.2.4 | 0.06% | 0.07% | 0.05% | 106% | 102% | 0.13% | 0.16% | 0.10% | 100% | 98% |
| CE8.2.5a | 0.07% | 0.09% | 0.03% | 104% | 98% | 0.13% | 0.08% | 0.10% | 104% | 99% |
| CE8.2.5b | 0.09% | 0.10% | 0.06% | 111% | 105% | 0.11% | 0.18% | 0.12% | 105% | 101% |
| CE8.2.6 | 0.09% | 0.10% | 0.06% | 106% | 101% | 0.13% | 0.20% | 0.11% | 100% | 98% |
| Class F | VTM+PLT | -11.43% | -8.94% | -9.04% | 117% | 89% | -8.52% | -8.02% | -8.31% | 110% | 101% |
| CE8.2.1 | -11.43% | -8.94% | -9.04% | 117% | 89% | -8.52% | -8.02% | -8.31% | 110% | 101% |
| CE8.2.1\* | -5.55% | -6.57% | -7.23% | 114% | 95% | -3.89% | -5.15% | -5.83% | 111% | 102% |
| CE8.2.2 | -11.65% | -9.08% | -9.19% | 118% | 91% | -8.80% | -8.28% | -8.66% | 110% | 101% |
| CE8.2.3 | -11.41% | -8.92% | -8.98% | 118% | 93% | -8.47% | -8.06% | -8.26% | 103% | 95% |
| CE8.2.4 | -11.50% | -8.30% | -8.35% | 117% | 93% | -8.56% | -7.60% | -7.78% | 102% | 95% |
| CE8.2.5a | -9.75% | -9.29% | -10.06% | 113% | 86% | -7.51% | -7.08% | -8.08% | 107% | 96% |
| CE8.2.5b | -11.43% | -8.94% | -9.04% | 121% | 94% | -8.65% | -7.95% | -8.32% | 110% | 102% |
| CE8.2.6 | -11.43% | -8.83% | -8.89% | 116% | 92% | -8.54% | -8.01% | -8.25% | 102% | 95% |
| SCC 1080p | VTM+PLT | -33.06% | -27.59% | -27.70% | 131% | 68% | -15.71% | -14.68% | -14.53% | 106% | 93% |
| CE8.2.1 | -33.06% | -27.59% | -27.70% | 131% | 68% | -15.71% | -14.68% | -14.53% | 106% | 93% |
| CE8.2.1\* | -17.97% | -18.43% | -18.73% | 122% | 81% | -9.03% | -10.12% | -10.01% | 106% | 96% |
| CE8.2.2 | -34.47% | -28.70% | -28.82% | 122% | 70% | -16.56% | -15.23% | -15.12% | 105% | 94% |
| CE8.2.3 | -33.03% | -27.60% | -27.66% | 126% | 67% | -15.73% | -14.64% | -14.50% | 99% | 87% |
| CE8.2.4 | -33.15% | -26.95% | -27.08% | 127% | 69% | -15.77% | -14.33% | -14.23% | 99% | 88% |
| CE8.2.5a | -27.02% | -26.01% | -25.52% | 126% | 62% | -14.78% | -15.28% | -14.62% | 102% | 88% |
| CE8.2.5b | -33.06% | -27.59% | -27.70% | 135% | 69% | -16.64% | -15.24% | -15.02% | 108% | 94% |
| CE8.2.6 | -33.13% | -27.64% | -27.75% | 128% | 71% | -15.73% | -14.59% | -14.50% | 99% | 89% |

8.1.x

The following question is discussed: Should CTC enable CPR for class F? This would be realistic for the case where the encoder could know that it is screen content or natural content.

The methods of CE8.1.2 provide additional gain of >3% for class F, 8% for TGM class. These are re-using existing data from the previous CTU (assuming 2 or 4 buffers of size 64x64 each, depending on version). This is generally agreed to be practical and give good benefit. It could however be coplicated to specify as an encoder/bitstream restriction that the limits of CPR vectors are valid.

Shan Liu and other interested experts were asked to inspect the specification text (all 4 versions a…d), and it was reported back that version a was the most practical solution.

Decision: Adopt JVET-M0407 (variant a).

The methods of CE8.1.1 provide additional gain (0.4% class F, 0.9% for class TGM), but modify AMVP and merge list construction. Question is raised whether VVC would require to use exactly the same principle for CPR and normal MV coding. Probably this might be OK if it does not deviate too much, and does not require much additional processing. In HEVC SCC, it was required to have exactly the same process for CPR and MV coding, which may not be the case for VVC.

See the notes of further discussion in the JVET Sunday plenary about general design limitations we would impose on CPR vector coding

8.1.3 uses the line/columns buffers at CTU boundary (which is there for intra prediction) to enable CPR by one line/column more across CTU boundary. Gives 0.1% for class F, 0.2% for TGM. Probably, part of that gain (as far as the left boundary is concerned) is overlapping with 8.1.2.

A combination on top of 8.1.2.d was reported in JVET-M0878. It seemed that the additional benefit was very small, so no action was taken on it.

8.2.x

Current VVC does not include palette mode, however a kind of “baseline” exists which is HEVC palette plus dual tree. This provides roughly 3%/7.5% gain over VVC+CPR for classes F/TGM. Results from CE also indicate that this gain goes to 2.5%/4.5% when combined with the improved CPR from 8.1.2. This may be even less when other aspects such as transform skip come into play. Such a relative low gain might not justify adding

See the notes of further discussion in the JVET Sunday plenary – regarding the design targets for palette, improved compression performance may be more important than reducing complexity.

8.2.2 is a method that performs intra prediction and provides one signal in the palette that inserts the predicted sample instead of inserting a value from the palette. Gain is very low, and does not justify the additional complexity.

8.2.3 targets complexity reduction of (index map scan order is constrained by the block shape). Results show minimum loss compared to 8.2.1 (CE palette basis). At the current status of palette, no urgent need to make such changes of the basis method.

8.2.4 uses separate trees (and separate palettes for luma and chroma), but the chroma part can only use palette mode, if the corresponding luma area entirely uses palette. The palette mode signalling is removed for such CUs where it is not the case. This however introduces some dependency (including parsing) which does not allow independent decoding of luma and chroma trees any more. Furthermore, the benefit on compression is practically zero.

It is understood that the intent is to disallow cases where the luma does not use palette and the chroma uses it. However, this could also be achieved by an encoder only decision.

8.2.5a uses one tree but allows different palettes for luma and chroma. This performs better than 8.2.1\*, which uses one tree and one palette. It however performs still worse than 8.2.1 which uses separate trees and separate palettes for luma and chroma. This indicates that only part of the gain of 8.2.1 versus 8.2.1\* comes from the different palettes, another part comes from different partitioning.

8.2.5b is identical to 8.2.1 for intra coding, but uses same tree (but different palettes) for inter coding. For RA this gives <0.4% in TGM; <0.1% in class F (with CPR on), With CPR off, the gain is 0.9+% (TGM) amd 0.1+% (class F). At the current status of palette, no urgent need to make such changes of the basis method. It provides some (small) gain, and this aspect should be further studied. There is also a CE related proposal on this.

8.2.6 targets better compression performing by predicting the palette. This however can only be observed for the palette only compression, and is very small (0.06% for class TGM).

8.3.x

These approaches perform sample-wise DPCM as an additional concept that demonstrates some benefit for screen content types. The most viable approach (according to proponents) is 8.3.2 which can best be optimized in terms of throughput and also shows best compression. The gain over VTM+CPR is 3.7%/4.9% for classes F/TGM, and gain over VTM+CPR+PLT is 1.3%/1.4%, respectively. The encoder runtimes are significantly faster when those methods are used, as some early termination approach is employed (not searching other intra modes when the prediction works well).

The current method uses a maximum of 12 context coded bins per sample, which is much too large.

Furthermore, this would be yet another alternative prediction method (and building block) which needs to be implemented in parallel with existing ones, which needs some justification in terms of compression performance to be included.

Could the residual coding be unified with the existing approach of VVC (in that case, the method could just be seen as another intra prediction mode with transform skip)?

It is also asked how the current residual coding method would perform in the low QP range

Further study necessary.

(include summaries of contribution from JVET-M0028 subsequently)

[JVET-M0050](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4852) CE8: Palette Mode in HEVC (test 8.2.1) [Y.-C. Sun, J. Lou (Alibaba), Y.-H. Chao, H. Wang, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-M0051](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4853) CE8: Palette Mode and Intra Mode Combination (test 8.2.2) [Y.-C. Sun, J. Lou (Alibaba)]

[JVET-M0052](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4854) CE8: Separate Palette Coding for Luma and Chroma (test 8.2.5) [Y.-C. Sun, J. Lou (Alibaba), Y.-H. Chao, H. Wang, V. Seregin, M. Karczewicz (Qualcomm), R. Chernyak, S. Ikonin, J. Chen (Huawei)]

[JVET-M0056](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4858) CE8: BDPCM with LOCO-I and independently decodable areas (test 8.3.1a) [F. Henry, A. Mohsen (Orange), P. Philippe, G. Clare (B-com)]

[JVET-M0057](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4859) CE8: BDPCM with horizontal/vertical predictor and independently decodable areas (test 8.3.1b) [F. Henry, M. Abdoli, P. Philippe, G. Clare (Orange)]

[JVET-M0058](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4860) CE8: BDPCM with modified binarization (test 8.3.2) [F. Henry, M. Abdoli, G. Clare, P. Philippe (Orange)]

[JVET-M0332](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5139) CE8: Block vector prediction for CPR (test 8.1.1a and test 8.1.1b) [J. Nam, J. Lim, S. Kim (LGE)]

[JVET-M0407](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5215) CE8: CPR reference memory reuse without increasing memory requirement (CE8.1.2a and CE8.1.2d) [X. Xu, X. Li, S. Liu (Tencent), E. Chai (Ubilinx)]

[JVET-M0408](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5216) CE8: CPR reference memory reuse with reduced memory requirement (CE8.1.2b and CE8.1.2c) [X. Xu, X. Li, S. Liu (Tencent), E. Chai (Ubilinx)]

[JVET-M0455](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5264) CE8: Palette index map scan order constraints (Test 8.2.3) [J. Ye, X. Xu, M. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0456](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5265) CE8: palette mode when dual-tree is enabled (Test 8.2.4) [J. Ye, X. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0457](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5266) CE8: Palette predictor list enhancement (Test 8.2.6) [J. Ye, X. Xu, M. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0474](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5284) CE8.1.3: Extended CPR reference with 1 buffer line [L. Pham Van, V. Seregin, W.-J. Chien, T. Hsieh, M. Karczewicz (Qualcomm)]

[JVET-M0543](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5356) Crosscheck of M0474: CE8.1.3- Extended CPR reference with 1 buffer line [S.Paluri, S. Kim (LGE)] [late]

## CE9: Decoder-side motion vector derivation (8)

Contributions in this category were discussed Thursday 10 Jan. 2030–2230 (Track B chaired by JRO).

[JVET-M0029](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5498) CE9: Summary report on decoder side motion vector derivation [X. Xiu, S. Esenlik]

The core experiment summary report is organized into 2 sub-tests as follows:

* CE9.1: BDOF design (3 tests)
* CE9.2: DMVR design (24 tests)

CE9.1: BDOF design

|  |  |  |  |
| --- | --- | --- | --- |
| # | Description | Tester | Cross-checker |
| 9.1.1.a | 1. use 8-tap DCTIF filters to generate the prediction samples in extended region and inside CU  2. padding for reference samples outside [w+7, h+7] for final MC (DCTIF) | Xiu, Xiaoyu | H. Liu |
| 9.1.1.b | 1. use integer positions to generate the prediction samples in extended region  2. use 8-tap DCTIF filters to generate the prediction samples inside CU | Xiu, Xiaoyu | H. Liu |
| 9.1.1.c | 1. apply different gradient calculation method for prediction samples on the CU boundaries and inside CU  2. use 8-tap DCTIF filters to generate the prediction samples inside CU | Xiu, Xiaoyu | H. Liu |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  | **VTM** | | | | | **Crosscheck** | |
| **Test** | **Document** | **Crosschecker** | **Y** | **U** | **V** | **EncT** | **DecT** | **EncT** | **DecT** |
| 9.1.1 a | JVET-M0487 | H. Liu | -0.01% | 0.03% | 0.02% | 103% | 102% | 105% | 104% |
| 9.1.1 b | H. Liu | 0.05% | 0.02% | 0.02% | 99% | 98% | 99% | 100% |
| 9.1.1 c | H. Liu | 0.10% | 0.03% | 0.01% | 99% | 98% | 100% | 100% |

9.1.1.a does not simplify, replaces bilinear filters in extended region by DCTIF

9.1.1.b simplifies by using no interpolation in extended region (just integer positions)

9.1.1.c changes the gradient calculation at boundaries and does not need extended region any more, it simplifies, but the design becomes less unified

Several experts supported 9.1.1.b as the best simplified design approach.

Decision: Adopt JVET-M0487 (solution 9.1.1.b)

Specification text was made available, to be confirmed to be consistent with software by cross-checkers, and reviewed by spec editors.

CE9.2: DMVR design

|  |  |  |
| --- | --- | --- |
| # | Description | Document |
| 9.2.1 a  DMVR base s/w | 1. padding for reference samples outside [w+7, h+7] for final MC (DCTIF)  2. use bi-linear filter to generate prediction samples [w+4, h+4] for motion refinement  3a. MRSAD is used as metric for motion refinement  3b. MRSAD calculation on every other row  4. error surface based sub-pixel refinement  5a. DMVR early termination based on MV distance  5b. DMVR early termination based on sample difference  Block size criteria: CUs with height >= 8 and size > 64 and CUs with size <= 1024  Refined MV: MC, DBF, TMVP, spatial MV prediction from top and top-left CTU | JVET-M0147 ([S. Sethuraman](mailto:sriram.sethuraman@ittiam.com)) |
| 9.2.1 b0 | CE9.2.1a + Integer DMVR, SAD, and refined MV used only for MC |
| 9.2.1 b | CE9.2.1b0 + Enable 32x32 forced split + enable DMVR for w\*h > 1024 + Replace CU level early termination to Sub-PU level |
| 9.2.1 c | CE9.2.1b + Replace SAD with MR-SAD |
| 9.2.1 d | CE9.2.1c + Replace Integer DMVR with Bilinear MC |
| 9.2.1 e | CE9.2.1d + use of refined MV for deblocking, TMVP and for spatial MV prediction from top/top-left CTU neighbors |
| 9.2.1 f | CE9.2.1e + use of refined MV also within CTU row from VPDUs that were processed 2 VPDUs behind current VPDU |
| 9.2.1 f1 | CE9.2.1f + MC restricted to use samples within (64+7)\*(64+7) for VPDU of CUs larger than 64x64 |
| 9.2.1 g | CE9.2.1e + replace sub-PU size to 16x16 from 32x32 |
| 9.2.2 c | CE9.2.1g + replace MR-SAD with PR-MR-SAD | JVET-M0147 ([S. Sethuraman](mailto:sriram.sethuraman@ittiam.com)) |
| 9.2.2 d | CE9.2.2c + Change sub-CU level early termination threshold (3 times) to know DecT impact |
| \*9.2.2 f | Results for CE9.2.2c when BDOF is disabled in both VTM3.0 and with DMVR + DMVR is enabled for ATMVP and MMVD |
| 9.2.2 f1 | Disabling refined MV usage for anything other than MC in CE9.2.2c |
| 9.2.2 f2 | Replacing PR-MR-SAD with SAD in CE9.2.2c |
| 9.2.3 a | No diagonal direction checking when all cross points' cost value not less than center point cost value | JVET-M0306 ([X.Chen](mailto:sriram.sethuraman@ittiam.com)) |
| 9.2.3 b | Down sampling for MRSAD's mean value calculation |
| 9.2.3 c | Replacing MRSAD with SAD in CE9.2.1a |
| 9.2.4 a | CE9.2.1a + allow inter reconstruction to be used as intra reference | JVET-M0447 (M. Xu) |
| 9.2.4 b | CE9.2.1a + don't allow inter reconstruction to be used as intra reference |
| 9.2.4 c | CE9.2.1a + don't allow DMVR reconstruction to be used as intra reference |
| 9.2.5 a | CE9.2.1a is changed as follows:  minCost equal to zero replaces minCost less than (w\*h\*(1<<(Max(2, 14 – Bit Depth) + (Bit Depth-8)+0)) | JVET-M0062 (T. Chujoh ) |
| 9.2.5 b | CE9.2.1a is changed as follows:  minCost equal to zero replaces minCost less than (w\*h\*(1<<(Max(2, 14 – Bit Depth) + (Bit Depth-8)-1)) |
| 9.2.6 | CE9.2.1a is changed as follows:  Disable DMVR for CUs with size > 4096 | JVET-M0076 (K. Unno) |
| 9.2.7 | CE9.2.1a is changed as follows:  Bilinear filter is replaced by no interpolation (rounding to nearest integer sample) | JVET-M0287 (S. Esenlik) |

\* Below, CE9.2.2.f result is reported compared to BDOF off anchor.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | **VTM** | | | | |
| **Test** | **Description** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 9.2.1 a  DMVR base s/w | 1. padding for reference samples outside [w+7, h+7] for final MC (DCTIF)  2. use bi-linear filter to generate prediction samples [w+4, h+4] for motion refinement  3a. MRSAD is used as metric for motion refinement  3b. MRSAD calculation on every other row  4. error surface based sub-pixel refinement  5a. DMVR early termination based on MV distance  5b. DMVR early termination based on sample difference  Block size criteria: CUs with height >= 8 and size > 64 and CUs with size <= 1024  Refined MV: MC, DBF, TMVP, spatial MV prediction from top and top-left CTU  DMVR is enabled for ATMVP and MMVD (disabled for all other tests exceptz 9.2.3ff.) | -0.71% | -0.81% | -0.87% | 110% | 118% |
| 9.2.1 b0 | CE9.2.1a + Integer DMVR, SAD, and refined MV used only for MC | -0.30% | -0.39% | -0.40% | 101% | 103% |
| 9.2.1 b | CE9.2.1b0 + Enable 32x32 forced split + enable DMVR for w\*h > 1024 + Replace CU level early termination to Sub-PU level | -0.58% | -0.86% | -0.86% | 102% | 106% |
| 9.2.1 c | CE9.2.1b + Replace SAD with MR-SAD | -0.66% | -0.88% | -0.92% | 102% | 108% |
| 9.2.1 d | CE9.2.1c + Replace Integer DMVR with Bilinear MC | -0.74% | -1.02% | -1.07% | 102% | 111% |
| 9.2.1 e | CE9.2.1d + use of refined MV for deblocking, TMVP and for spatial MV prediction from top/top-left CTU neighbors | -1.12% | -1.25% | -1.30% | 103% | 114% |
| 9.2.1 f | CE9.2.1e + use of refined MV also within CTU row from VPDUs that were processed 2 VPDUs before current VPDU | -1.25% | -1.33% | -1.43% | 103% | 114% |
| 9.2.1 f1 | CE9.2.1f + MC restricted to use samples within (64+7)\*(64+7) for VPDU of CUs larger than 64x64 | -1.25% | -1.33% | -1.42% | 103% | 114% |
| 9.2.1 g | CE9.2.1e + replace sub-PU size to 16x16 from 32x32 | -1.13% | -1.33% | -1.44% | 103% | 118% |
| 9.2.2 c | CE9.2.1g + replace MR-SAD with PR-MR-SAD | -1.07% | -1.27% | -1.36% | 103% | 118% |
| 9.2.2 d | CE9.2.2c + Change sub-CU level early termination threshold (3 times) to know DecT impact | -1.04% | -1.27% | -1.36% | 103% | 117% |
| \*9.2.2 f | Results for CE9.2.2c when BDOF is disabled in both VTM3.0 and with DMVR + DMVR is enabled for ATMVP and MMVD | -1.51% | -1.58% | -1.59% | 116% | 126% |
| 9.2.2 f1 | Disabling refined MV usage for anything other than MC in CE9.2.2c | -0.72% | -1.05% | -1.11% | 102% | 115% |
| 9.2.2 f2 | Replacing PR-MR-SAD with SAD in CE9.2.2c | -1.02% | -1.29% | -1.35% | 103% | 115% |
| 9.2.3 a | CE9.2.1a, No diagonal direction checking when all cross points' cost value not less than center point cost value | -0.71% | -0.84% | -0.90% | 108% | 116% |
| 9.2.3 b | CE9.2.1a, Down sampling for MRSAD's mean value calculation | -0.68% | -0.84% | -0.89% | 108% | 115% |
| 9.2.3 c | CE9.2.1a, Replacing MRSAD with SAD | -0.60% | -0.78% | -0.84% | 107% | 115% |
| 9.2.4 a | CE9.2.1a + allow inter reconstruction to be used as intra reference | -0.71% | -0.81% | -0.87% | 108% | 115% |
| 9.2.4 b | CE9.2.1a + don't allow inter reconstruction to be used as intra reference | 3.87% | 8.82% | 9.62% | 103% | 113% |
| 9.2.4 c | CE9.2.1a + don't allow DMVR reconstruction to be used as intra reference | -0.46% | -0.34% | -0.36% | 108% | 115% |
| 9.2.5 a | CE9.2.1a is changed as follows:  minCost equal to zero replaces minCost less than (w\*h\*(1<<(Max(2, 14 – Bit Depth) + (Bit Depth-8)+0)) | -0.67% | -0.80% | -0.86% | 109% | 118% |
| 9.2.5 b | CE9.2.1a is changed as follows:  minCost equal to zero replaces minCost less than (w\*h\*(1<<(Max(2, 14 – Bit Depth) + (Bit Depth-8)-1)) | -0.70% | -0.81% | -0.87% | 109% | 119% |
| 9.2.6 | CE9.2.1a is changed as follows:  Disable DMVR for CUs with size > 4096 | -0.89% | -0.99% | -1.08% | 111% | 119% |
| 9.2.7 | CE9.2.1a is changed as follows:  Bilinear filter is replaced by no interpolation (rounding to nearest integer sample) | -0.58% | -0.69% | -0.74% | 109% | 115% |

Additional results in JVET-M0147 which show results on CE9.2.1g but without using refined MV for spatial MV prediction and deblocking: Overall -1.01%. This could be a reasonable approach avoiding some of the dependency problems that were observed in DMVR before. It was asked for some cross-check and specification text to be made available.

Cross check became available as M0887. Has two results: For MR-SAD and SAD. MR-SAD -1.01%, SAD -0.92%. Results provided above are confirmed. Specification text was provided in M0147v5, has been investigated by cross-checker and spec editor as being appropriate.

Decoding time increase is reported as 15%.

It was confirmed that the following criteria are fulfilled by the SAD version, which are agreed to be a tradeoff between software and hardware implementation aspects:

* Early termination w/ (0,0) position SAD between list0 and list1
* Block sizes for DMVR W\*H>=64 && H>=8
* Split the CU into multiple of 16x16 sub-blocks for DMVR of CU size > 16\*16
* Reference block size (W+7)\*(H+7) (for luma)
* 25 points SAD-based integer-pel search (i.e. (+-) 2 refinement search range, single stage)
* Bilinear-interpolation based DMVR
* MVD mirroring between list0 and list1 to allow bilateral matching
* “Parametric error surface equation” based sub-pel refinement
* Luma/chroma MC w/ reference block padding (if needed)
* Refined MVs used for MC and TMVPs only

It is further noted that the proposal contains an additional element which checks the MV difference with regard to previous MVs in the merge list to make an early termination in DMVR. This has hardly any impact on the BD rate, but reduces decoding time by 3%. This has however some impact on hardware implementation, and decoding time is not overly critical.

Further reducing decoding time for software implementation (and possible optimization of code) is desirable.

Decision: Adopt JVET-M0147 with SAD cost function, and without the MVD based early termination check.

Note that the MVD based early termination should also not be used in upcoming CEs.

It is noted that disallowing DMVR blocks for intra prediction may not be that relevant in practical pipeline implementations. Typically, within a CTU first all inter blocks would be reconstructed, and finally the intra coded blocks,

Early termination approaches do not seem to be very effective in terms of runtime reduction, and also are not beneficial for hardware.

Generally, the investigation on DMVR has led to a point where it might be manageable implementation-wise (not low complex, but still giving around 1% gain)

A problem of the methods investigated in the CE could still be that DMVR and BDOF could be applied sequentially, before finally motion comp and reconstruction can be done. JVET-M0223 considers this issue.

The next step was review of CE related contributions (there were not too many on DMVR) and the assess whether they provide further improvement or complexity reduction.

Revisit: Come to a conclusion on status of DMVR

A BoG was established (coordinated by S. Esenlik) to review the CE9 related contributions and suggest aspects to be studied in a CE (for BIO and DMVR). See the notes for the BoG report JVET-M0858.

(include summaries of contribution from JVET-M0029 subsequently)

[JVET-M0062](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4864) CE9: An early termination of DMVR (Test 9.2.5) [T. Chujoh, T. Ikai (Sharp)]

[JVET-M0076](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4879) CE9: Block size restriction for DMVR (test 9.2.6) [K. Unno, K. Kawamura, S. Naito (KDDI)]

[JVET-M0147](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4955) CE9: Results of DMVR related Tests CE9.2.1 and CE9.2.2 [S. Sethuraman (Ittiam)]

[JVET-M0887](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5718) Crosscheck of additional tests in JVET-M0147 (CE9: Results of DMVR related Tests CE9.2.1 and CE9.2.2) [T. Chujoh, T. Ikai (Sharp)] [late]

[JVET-M0903](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5734) Crosscheck of additional results of JVET-M0147 (CE9: Results of DMVR related Tests CE9.2.1 and CE9.2.2) [K. Kondo, M. Ikeda (Sony)] [late] [missing at end of meeting]

[JVET-M0287](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5094) CE9: Integer DMVR (Test 9.2.7) [S. Esenlik, H. Gao, A.M. Kotra, B. Wang, J. Chen (Huawei)]

[JVET-M0306](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5113) CE9: DMVR Simplifications (Test 9.2.3) [X. Chen, J. Zheng (HiSilicon)]

[JVET-M0447](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5256) CE9: Constrained intra prediction with DMVR (test 9.2.4) [M. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0487](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5297) CE9: Simplifications on bi-directional optical flow (BDOF) (test 9.1.1) [X. Xiu, Y. He (InterDigital), C.-Y. Lai, Y.-C. Su, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

## CE10: Combined and multi-hypothesis prediction (15)

Contributions in this category were discussed Saturday 12 Jan. 1100–1345 and 1515-1815 (Track B chaired by JRO).

[JVET-M0030](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5353) CE10: Summary report on combined and multi-hypothesis prediction [C.-W. Hsu, M. Winken]

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: multiple shape prediction partitions,
* CE10.4: diffusion filtering of inter- and intra-prediction signals,
* CE10.5: local illumination compensation.

There are 13, 4, 1, 2 and 2 tests for each sub CE, respectively.

CE proposals are listed as follows,

|  |  |  |  |
| --- | --- | --- | --- |
| Proposal Document # | Corresponding Tests | Author(s) | Title |
| JVET-M0176 | CE10.1.1 | M.-S. Chiang, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek) | CE10.1.1: Multi-hypothesis prediction for improving non-skip & non-merge inter mode and merge mode |
| JVET-M0425 | CE10.1.2 | [M. Winken](mailto:martin.winken@hhi.fraunhofer.de), H. Schwarz, D. Marpe, T. Wiegand (HHI) | CE10: Multi-hypothesis inter prediction (Test 10.1.2) |
| JVET-M0290 | CE10.1.3 | [W. Xu](mailto:xuweiwei3@huawei.com), [B. Wang](mailto:biao.wang@huawei.com), H. Yang, J. Chen (Huawei) | CE10: Simplification on Combined Inter-Intra Prediction (Test 10.1.3) |
| JVET-M0177 | CE10.1.4 | M.-S. Chiang, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek) | CE10.1.4: Simplification of combined inter and intra prediction |
| JVET-M0293 | CE10.1.5 | [W. Xu](mailto:xuweiwei3@huawei.com), [B. Wang](mailto:biao.wang@huawei.com), H. Yang, J. Chen (Huawei), [M.-S. Chiang](mailto:man-shu.chiang@mediatek.com), C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek) | CE10: Simplification on Combined Inter-Intra Prediction with size restriction (Test 10.1.5) |
| JVET-M0178 | CE10.2.1 | Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, C.-W. Hsu, C.-C. Chen, Y.-C. Lin, Y.-W. Huang, S.-M. Lei (MediaTek), X. Xiu, Y. He (InterDigital) | CE10.2.1: Uni-prediction-based CU-boundary-only OBMC |
| JVET-M0179 | CE10.2.2 | Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, C.-W. Hsu, C.-C. Chen, Y.-C. Lin, Y.-W. Huang, S.-M. Lei (MediaTek), X. Xiu, Y. He (InterDigital) | CE10.2.2: Integer-MV-based CU-boundary-only OBMC |
| JVET-M0180 | CE10.2.3 | Y.-C. Lin, C.-C. Chen, C.-W. Hsu, Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek) | CE10.2.3: Subblock OBMC with uni-prediction-based OBMC at CU boundaries |
| JVET-M0181 | CE10.2.4 | Y.-C. Lin, C.-C. Chen, C.-W. Hsu, Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek) | CE10.2.4: Subblock OBMC with integer-MV-based OBMC at CU boundaries |
| JVET-M0189 | CE10.3.1 | [Y. Ahn](mailto:yjahn@digitalinsights.co.kr), [D. Sim (Digital Insights)](mailto:dgsim@digitalinsights.co.kr) | CE10.3.1: AMVP mode for triangle prediction |
| JVET-M0042 | CE10.4.1  CE10.4.2 | [J. Rasch](mailto:Jennifer.Rasch@hhi.fraunhofer.de), [A. Henkel](mailto:anastasia.henkel@hhi-extern.fraunhofer.de), [J. Pfaff](mailto:Jonathan.pfaff@hhi.fraunhofer.de),[H. Schwarz](mailto:heiko.schwarz@hhi.fraunhofer.de), [D. Marpe](mailto:detlev.marpe@hhi.fraunhofer.de), [T. Wiegand (HHI)](mailto:thomas.wiegand@hhi.fraunhofer.de) | CE10: Uniform Directional Diffusion Filters For Video Coding |
| JVET-M0087 | CE10.5.2 | [K. Abe](mailto:abe.kiyo@jp.panasonic.com), [T. Toma](mailto:toma.tadamasa@jp.panasonic.com),[J. Li (Panasonic)](mailto:jingya.li@sg.panasonic.com) | CE10: Low pipeline latency LIC (test 10.5.2) |
| JVET-M0112 | CE10.5.3 | [P. Bordes](mailto:philippe.bordes@technicolor.com), [T. Poirier](mailto:tangi.poirier@technicolor.com), [F. LeLeannec (Technicolor)](mailto:fabrice.leleannec@technicolor.com) | CE10: LIC confined within current CTU (test 10.5.3) |

CE10.1: Multi-hypothesis prediction

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Supported modes | Signaling of hypothesis | # of additional hypotheses | Block constraint in luma samples | BW reduction technique | Hypothesis inheritance | Reference frame access constraints | Color components |
|  |  |  |  |  |  |  |  |  |
| CE10.1.1.a | AMVP (uni only) | merge index | 1 | >= 8x8 |  |  | up to 2 | luma + chroma |
| JVET-M0176 |  |  |  |  |  |  |  |  |
| CE10.1.1.b  JVET-M0176 | skip/merge  (uni or bi) | merge index (implicitly derived) | 1 or 2 |  | full-pel for additional hypotheses | no temporal | up to 4 | luma + chroma |
|  |  |  |  |  | (luma) | spatial: no CTU constraints |  |  |
| CE10.1.2.a  JVET-M0425 | merge AMVP | ref index + mvp index + MVDs + weight index | 1 or 2 | > 8x8 | full-pel for additional hypotheses | no temporal | up to 4 | luma + chroma |
|  |  |  |  |  | (luma + chroma) | spatial: from left or within CTU |  |  |
| CE10.1.2.b  JVET-M0425 | merge AMVP | ref index + mvp index + MVDs + weight index | 1 or 2 | > 8x8 | full-pel for additional hypotheses | not allowed | up to 4 | luma + chroma |
|  |  |  |  |  | (luma + chroma) |  |  |  |
| CE10.1.2.c  JVET-M0425 | merge AMVP | ref index + mvp index + MVDs + weight index | 1 or 2 | > 8x8 | full-pel for additional hypotheses | no temporal | up to 2 | luma + chroma |
|  |  |  |  |  | (luma + chroma) | spatial: from left or within CTU |  |  |
| CE10.1.2.d  JVET-M0425 | merge AMVP | ref index + mvp index + MVDs + weight index | 1 or 2 | > 8x8 | full-pel for additional hypotheses | no temporal | up to 4 | luma |
|  |  |  |  |  | (luma + chroma) | spatial: from left or within CTU |  |  |

The test results for this aspect are summarized as follows,

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | Config. |  |  | VTM |  |  |
|  |  |  | Y | U | V | EncT | DecT |
| CE10.1.1.a | JVET-M0176 | RA | -0.17% | -0.13% | -0.10% | 107% | 100% |
|  |  | LB | 0.00% | 0.10% | 0.25% | 107% | 101% |
| CE10.1.1.b | JVET-M0176 | RA | -0.17% | -0.25% | -0.22% | 103% | 102% |
|  |  | LB | -0.12% | -0.19% | -0.17% | 103% | 102% |
| CE10.1.2.a | JVET-M0425 | RA | -0.29% | -0.16% | -0.12% | 107% | 97% |
|  |  | LB | -0.41% | -0.04% | -0.04% | 110% | 99% |
| CE10.1.2.b | JVET-M0425 | RA | -0.20% | -0.02% | -0.05% | 107% | 96% |
|  |  | LB | -0.30% | -0.10% | -0.17% | 111% | 102% |
| CE10.1.2.c | JVET-M0425 | RA | -0.20% | -0.10% | -0.08% | 105% | 97% |
|  |  | LB | -0.20% | -0.19% | -0.24% | 107% | 100% |
| CE10.1.2.d | JVET-M0425 | RA | -0.29% | 0.03% | 0.04% | 107% | 96% |
|  |  | LB | -0.40% | 0.06% | -0.02% | 110% | 99% |

According to the CE description, for investigating the impact of multi-hypothesis inter prediction on cache-related aspects, the cache model compiled into the reference decoder software by setting #define JVET\_J0090\_MEMORY\_BANDWITH\_MEASURE to 1 is used, in conjunction with the cache config file provided in JVET-K0451. For each bit stream, the decoder outputs a total hit ratio when using the cache model. The following table compares the average hit ratios (in percentage) of the tests with those of VTM-3.0:

data quoted from JVET-M0176:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | | |
|  | **VTM-3.0 (%)** | | | **CE10.1.1.b (%)** | | |
|  |
| Class A1 | 99.4735 | | | 99.4663 | | |
| Class A2 | 99.5509 | | | 99.5461 | | |
| Class B | 99.5308 | | | 99.5249 | | |
| Class C | 99.3467 | | | 99.3435 | | |
| Class E |  | | |  | | |
| **Overall** | **99.4755** | | | **99.4702** | | |
| Class D | 99.3402 | | | 99.3401 | | |
| Class F (optional) | 98.8734 | | | 98.8607 | | |
|  |  |  |  | |  |  |
|  | **Low delay B Main10** | | | | | |
|  | **VTM-3.0 (%)** | | | **CE10.1.1.b (%)** | | |
|  |
| Class A1 |  | | |  | | |
| Class A2 |  | | |  | | |
| Class B | 99.6490 | | | 99.6414 | | |
| Class C | 99.5511 | | | 99.5415 | | |
| Class E | 99.5562 | | | 99.5517 | | |
| **Overall** | **99.5854** | | | **99.5782** | | |
| Class D | 99.5090 | | | 99.496 | | |
| Class F (optional) | 99.0382 | | | 99.0268 | | |

data quoted from JVET-M0425:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  |  |  | Random Access |  |  |
|  | VTM-3.0 | CE10.1.2.a | CE10.1.2.b | CE10.1.2.c | CE10.1.2.d |
| A1 | 99.4888 | 99.4781 | 99.4878 | 99.4858 | 99.4866 |
| A2 | 99.5513 | 99.5474 | 99.5505 | 99.5488 | 99.5505 |
| B | 99.5340 | 99.5259 | 99.5330 | 99.5326 | 99.5345 |
| C | 99.3629 | 99.3593 | 99.3615 | 99.3630 | 99.3634 |
| **Overall** | **99.4843** | **99.4777** | **99.4832** | **99.4826** | **99.4838** |
| D | 99.3416 | 99.3379 | 99.3412 | 99.3414 | 99.3415 |
| F | 98.9343 | 98.9258 | 98.9267 | 98.9297 | 98.9291 |
|  |  |  |  |  |  |
|  |  |  | Low Delay B | |  |
|  | VTM-3.0 | CE10.1.2.a | CE10.1.2.b | CE10.1.2.c | CE10.1.2.d |
| B | 99.6547 | 99.6462 | 99.6531 | 99.6539 | 99.6567 |
| C | 99.5650 | 99.5548 | 99.5594 | 99.5656 | 99.5628 |
| E | 99.5242 | 99.5147 | 99.5187 | 99.5224 | 99.5225 |
| **Overall** | **99.5813** | **99.5719** | **99.5771** | **99.5806** | **99.5807** |
| D | 99.5715 | 99.5657 | 99.5683 | 99.5727 | 99.5737 |
| F | 99.1095 | 99.0934 | 99.0978 | 99.1081 | 99.1034 |

1.1.a uses two hypotheses in uni prediction and merge. Basically, the same prediction could be invoked by using bi prediction. However, only one AMVP list is generated, and it may save some signalling. Encoder time increases by 7%, no gain in LB.

Are gains of 1.1.a/b additive? They are said to have been almost additive before this CE cycle, but in the current CE the combination was not tested.

Worst case memory BW of 1.1.a is uncritical, of 1.1.b was analysed as roughly 80% of VTM.

Combination of 1.1.a/b would be somewhat similar to 1.2.a, which uses multi hypothesis for both merge and AMVP, and additionally allows kind of different weighting of the hypotheses. 1.2.a is the “full set” of functionality of this proposal, whereas b..d are somewhat simplifications, mainly for the benefit of saving local storage (b), or memory bandwidth (c,d). d still uses up to 4 hypotheses (2 each in bi with >=8x16 block size restriction), but only for luma, which is the reason for worse performance in chroma. It is reported that worst case memory BW is 0.97%

It is also mentioned that potentially gains of 1.1.a might add up to 1.2.x.

Generally, the gain of all 1.1.x and 1.2.x proposals is significantly less than it was over VTM2 (cut by half or even more). In particular, the 1.1.b and 1.2.x proposals add need for more building blocks. 1.1.a is relatively simple and ce re-use existing memory access structures and MC logic, but for getting the gain of 0.17% for RA (no gain for LB), the encoder runtime also increases by 7%.

By doing more encoder checks and increasing runtime by 7%, probably it should be possible to get similar gain without a syntax change.

1.1.3…5 target simplification of VTM3 (CIIP)

For simplification aspects, the tests and corresponding results are summarized as follows, where the current design in VTM-3.0 and the differences between each test and VTM-3.0 are listed

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | Supported intra modes | Reference sample smoothing | PDPC | Weights for combined | CU constraints | Note |
|  |  |  |  |  |  |  |  |
| VTM-3.0 |  | 4: DC, PL, VER, HOR | Yes | Yes | PL, DC: equal weights | area >=64 |  |
|  |  |  |  |  | VER, HOR: fixed, position dependent weights | W<128 && H<128 |  |
| CE10.1.3.a | JVET-M0290 | 1: PL | Yes | Yes | equal weights |  |  |
|  |  |  |  |  |  |  |  |
| CE10.1.3.b | JVET-M0290 | 4: DC, PL, VER, HOR | No for PL\* | No for PL | PL, DC: equal weights |  |  |
|  |  |  |  |  | VER, HOR: fixed, position dependent weights |  |  |
| CE10.1.3.c | JVET-M0290 | 4: DC, PL, VER, HOR | Yes | Yes | equal weights |  |  |
|  |  |  |  |  |  |  |  |
| CE10.1.3.d | JVET-M0290 | 1: PL | No for PL\* | No | equal weights (4:4) |  | CE10.1.3.a + CE10.1.3.b |
|  |  |  |  |  | LD frame: 6:2\* |  |  |
| CE10.1.4 | JVET-M0177 |  |  |  |  | VTM constraints + |  |
|  |  |  |  |  |  | area <=1024 |  |
| CE10.1.5.a | JVET-M0293 | 1: PL |  |  | equal weights | VTM constraints + | CE10.1.3.a + CE10.1.4 |
|  |  |  |  |  |  | area <=1024 |  |
| CE10.1.5.b | JVET-M0293 | 1: PL |  | No | equal weights (4:4) | VTM constraints + | CE10.1.3.a + CE10.1.4 +  no PDPC |
|  |  |  |  |  | LD frame: 6:2\* | area <=1024 |  |

\* Not in original CE description.

The test results for this aspect are summarized as follows,

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | Config. |  |  | VTM |  |  |
|  |  |  | Y | U | V | EncT | DecT |
| CE10.1.3.a | JVET-M0290 | RA | -0.01% | 0.13% | 0.09% | 99% | 100% |
|  |  | LB | 0.10% | 0.35% | 0.36% | 99% | 100% |
| CE10.1.3.b | JVET-M0290 | RA | 0.01% | 0.00% | -0.02% | 100% | 100% |
|  |  | LB | 0.01% | -0.01% | -0.07% | 100% | 101% |
| CE10.1.3.c | JVET-M0290 | RA | 0.05% | 0.12% | 0.10% | 100% | 100% |
|  |  | LB | 0.10% | 0.18% | 0.05% | 100% | 100% |
| CE10.1.3.d | JVET-M0290 | RA | 0.02% | 0.07% | 0.03% | 99% | 100% |
|  |  | LB | 0.01% | 0.12% | 0.13% | 99% | 100% |
| CE10.1.4 | JVET-M0177 | RA | 0.01% | 0.02% | 0.05% | 99% | 102% |
|  |  | LB | 0.04% | -0.04% | 0.13% | 100% | 100% |
| CE10.1.5.a | JVET-M0293 | RA | 0.02% | 0.16% | 0.12% | 98% | 100% |
|  |  | LB | 0.11% | 0.23% | 0.29% | 98% | 100% |
| CE10.1.5.b | JVET-M0293 | RA | 0.06% | 0.07% | 0.03% | 98% | 100% |
|  |  | LB | 0.07% | 0.15% | 0.03% | 98% | 99% |

It is commented that 10.1.3.b/d was not originally planned in the CE.

In the context of reviewing 10.1.3.x proposals, the following aspects were identified in CIIP:

- does it need a specific MPM derivation? If there was only one mode (as in 10.1.3a/d) it is not needed at all, and it is mentioned that there are proposals just suggesting fixed length coding

- CIIP does not have any serious latency issue. Therefore, simplifications that remove some processing steps that are otherwise used in intra prediction is not necessary.

- Sample-wise unequal weighting is not an implementation issue, whereas equal weighting would be preferrable, unless it costs compression performance or causes qualty problems.

Beyond the solutions tested in 10.1.3 more study is necessary on these aspects.

10.1.4 requests restricting the maximum block size of CIIP to 32x32 (now it is 64x64). The motivation is saving need for additional memory. As however the maximum size of a inter-only or intra-only prediction block is large anyway, the real need for such a restriction is not obvious.

10.1.5 is combining some 10.1.3.x and 10.1.4.

CE10.2: OBMC

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | Applied boundaries | # of blending lines | BW reduction technique | Runtime reduction technique | Cost reduction technique |
|  |  |  |  |  |  |  |
| CE10.2.1 | JVET-M0178 | CU boundaries | 2: width < 8 (left); height < 8 (top)  4: otherwise | apply OBMC to uni-prediction blocks use uni-prediction to generate OBMC region | 1. reuse L shape buffer 2. apply CU size constraints | CTU row buffer removal |
|  |  |  |  |  | 3. apply MV merge 4. skip similar MVs |  |
| CE10.2.2 | JVET-M0179 | CU boundaries | 2: width < 8 (left); height < 8 (top)  3: otherwise | use integer MV to generate OBMC region | 1. reuse L shape buffer 2. apply CU size constraints | CTU row buffer removal |
|  |  |  |  |  | 3. apply MV merge 4. skip similar MVs |  |
| CE10.2.3 | JVET-M0180 | CU boundaries + sub-block boundaries | CU boundary:  2: width < 8 (left); height < 8 (top)   4: otherwise sub-block:   1: top, left, right | CU boundary:   apply OBMC to uni-prediction blocks  use uni-prediction to generate OBMC region | 1. reuse L shape buffer 2. apply CU size constraints | CTU row buffer removal |
|  |  |  | (when sub-block OBMC is applied, the number of blending line at CU boudnary is 1) | sub-block:   only apply to uni-prediction affine blocks | 3. apply MV merge 4. skip similar MVs |  |
| CE10.2.4 | JVET-M0181 | CU boundaries + sub-block boundaries | CU boundary:  2: width < 8 (left); height < 8 (top)   3: otherwise sub-blcok:   1: top, left, right | CU boundary:  use integer MV to generate OBMC region | 1. reuse L shape buffer 2. apply CU size constraints | CTU row buffer removal |
|  |  |  | (when sub-block OBMC is applied, the number of blending line at CU boudnary is 1) | sub-block:   only apply to uni-prediction affine blocks | 3. apply MV merge 4. skip similar MVs |  |

All proposals impose a CU size constraint >= 64 samples. It is requested to provide a more detailed analysis of the memory bandwidth. Likely, for processing on-the-fly, the worst case would be that the current block is 8x8, and all of the top and left neighbors are 4x4. Another option would be to store samples from the current block that were already fetched to perform interpolation in the neighbor blocks. In that case, it should be reported how large the additional local buffer would be, for all four methods.

Additional analysis is shown Sat. afternoon for 10.2.1 and 10.2.2 (to be provided in updated version of JVET-M0178/9). This analysis indicates that for those tw approaches the worst-case memory bandwidth of VVC is not increased for on-the-fly fetch (and even a little less for 10.2.2), or if the pre-generation method is used, the memory BW is even lower, but 1.96/1.28 kByte is necessary as local buffers.

In terms of processing, it is reported that worst case number of sample interpolations is not increased relative to the current bi prediction case. Method 10.2.1 uses uni prediction in a 8x8 block, and additionally needs to interpolate four 4x4 areas with other vectors for OBMC. Method 10.2.2 does not use any interpolations for OBMC. For 10.2.1, weighted superposition requires at most 4 shifts and 2 adds per sample. Furthermore, since the operations are locally varying, some additional logic is necessary. For 10.2.2., the latter numbers duplicate. Furthermore, 10.2.2 is more challenging in terms of local memory acces, as 6 different sources need to be blended.

10.2.1 seems manageable from complexity perspective (but definitely adds some complexity).

The test results are summarized as follows,

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | Config. |  |  | VTM |  |  |
|  |  |  | Y | U | V | EncT | DecT |
| CE10.2.1 | JVET-M0178 | RA | -0.27% | -0.58% | -0.62% | 104% | 103% |
|  |  | LB | -0.36% | -0.50% | -0.51% | 106% | 105% |
| CE10.2.2 | JVET-M0179 | RA | -0.37% | -0.91% | -0.90% | 105% | 104% |
|  |  | LB | -0.39% | -0.55% | -0.48% | 106% | 106% |
| CE10.2.3 | JVET-M0180 | RA | -0.39% | -0.59% | -0.63% | 105% | 104% |
|  |  | LB | -0.39% | -0.69% | -0.76% | 107% | 108% |
| CE10.2.4 | JVET-M0181 | RA | -0.49% | -0.91% | -0.87% | 106% | 105% |
|  |  | LB | -0.45% | -0.62% | -0.34% | 108% | 110% |
|  |  |  |  |  |  |  |  |

As a general note, the gain in compression performance is lower than it was with VTM2 (approx. half). However, from the results, OBMC even gives more gain for LB than for RA, and LB is in overall performance of VVC still worse than RA, this is assessed to be valuable enough. Some support, and no opposition is raised in track B against adopting it.

It was initially agreed in Track B to adopt JVET-M0178. Specification text was available. This decision was later reverted in the JVET Sunday plenary (see the notes in section 11.1).

This would have a high-level flag for disabling it.

CE10.3: Multiple shape prediction partitions

In CE10.3, the goal is to test AMVP to be combined with non-rectangular prediction partitions within one CU. The tests and corresponding results are summarized as follows,

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | Config. |  |  | VTM |  |  | Description |
|  |  |  | Y | U | V | EncT | DecT |  |
| CE10.3.1 | JVET-M0189 | RA | -0.06% | -0.03% | -0.06% | 123% | 100% | Two triangle prediction units (PUs) for AMVP mode |
|  |  | LB | -0.07% | -0.10% | -0.01% | 122% | 103% | Restricted to uni-prediction Restricted to RefIdx0 Applied to block width >= 8 && block height >= 8 |

From the results (low gain versus high increase in encoder run time), not worthwhile to consider

CE10.4: Diffusion filters for intra and inter prediction

In CE10.4, the goal is to test prediction to be combined using filtering, where three types of filters, two directional filters and one uniform filter are used. The filters are FIR filters, applied on the prediction signal, not iterative. The 1D filters are 9-tap, symmetric, only 1 multiplication, otherwise shifts. The 2D filter is a 5-tap diamond shape, only shift/add operations. At the boundaries, pixel replication is used.

The tests and corresponding results are summarized as follows,

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | Config. |  |  | VTM |  |  | Description |
|  |  |  | Y | U | V | EncT | DecT |  |
| CE10.4.1 | JVET-M0042 | AI | -0.19% | -0.03% | -0.03% | 123% | 101% | Uniform Diffusion filters with encoder speedup and simplified filter masks |
|  |  | RA | -0.44% | -0.51% | -0.35% | 113% | 98% |  |
|  |  | LB | -0.17% | 0.27% | 0.59% | 114% | 98% |  |
|  |  | LP | -0.86% | -0.26% | -0.11% | 119% | 97% |  |
| CE10.4.2 | JVET-M0042 | AI | -0.17% | -0.03% | -0.05% | 119% | 101% | Like CE10.4.1, but • In case of temporal layer depth larger than 3, no diffusion filter is applied |
|  |  | RA | -0.42% | -0.54% | -0.42% | 111% | 98% | • Simplified encoder search for intra blocks |
|  |  | LB | -0.17% | 0.41% | 0.43% | 113% | 98% |  |
|  |  | LP | -0.87% | -0.15% | -0.10% | 118% | 96% |  |

Generally, it was agreed that this method gives interesting gain, and is straightforward to implement at the decoder. Two concerns are raised:

- As it needs to be run after the prediction signal is generated, it produces additional delay in the intra prediction loop.

- For inter blocks, it can be used for 128x128 CU, which would break concepts of 64x64VPDU.

It is requested to provide additional results without using the method in intra prediction (and the intra part of CIIP), and restrict the largest CU size to 64x64.

It is also reported that a late contribution (JVET-M0848) provides new results for the same method of 10.4.2 with some (small) encoder speedup and slightly increased performance (-0.44% for luma).

Furthermore, it would be desirable to use only the prediction samples (no reconstructed samples from current picture). A version which did that was shown in the previous CE.

Was revisited (track B Thu 17 Jan.1630) after new results were made available in M0042v3. The restrictions were implemented as requested, including not using reconstructed samples from neighbour blocks. Results are as follows:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Random Access Main 10** | | | | |
|  | **Over VTM-3.0** | | | | |
|  | Y | U | V | EncT | DecT |
| Class A1 | -0.27% | -0.45% | -0.19% | 108% | 100% |
| Class A2 | -0.35% | -0.19% | -0.16% | 109% | 101% |
| Class B | -0.41% | -0.37% | -0.45% | 109% | 99% |
| Class C | -0.15% | -0.11% | -0.12% | 110% | 99% |
| Class E |  |  |  |  |  |
| **Overall** | -0.30% | -0.28% | -0.25% | 109% | 100% |
| Class D | -0.11% | -0.18% | -0.20% | 110% | 102% |
| Class F | -0.09% | -0.13% | -0.11% | 108% | 101% |

The spec text was available and straightforward.

One expert points out that the multiplication by 6 can be implemented by shift and add.

LB results are not complete yet, but by tendency similar as in the original scheme, lower gain than for RA.

Further study in CE, along with LIC and post rec filters. This CE should also identify how potentially gains add up. The restriction of not using recosntructed samples from neighboring inter blocks may not be necessary.

CE10.5: Local illumination compensation

In CE10.5, the goal is to test prediction to be combined using linear model derived from reconstructed and reference neighboring samples. The tests and corresponding results are summarized as follows,

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | Config. |  |  | VTM |  |  | Description |
|  |  |  | Y | U | V | EncT | DecT |  |
| CE10.5.2 | JVET-M0087 | RA | -0.56% | -0.31% | -0.37% | 135% | 99% | 1.      Remove all encoder and decoder LIC processes other than the reconstruction stage |
|  |  | LB | -0.51% | -0.44% | -0.58% | 140% | 101% | 2.      Modify bS calculation of DBF for LIC boundary. |
| CE10.5.3 | JVET-M0112 | RA | -0.44% | -0.31% | -0.34% | 134% | 101% | Based on CE10.5.2 |
|  |  | LB | -0.39% | -0.40% | -0.42% | 138% | 100% | LIC is confined to use reference samples only from the current CTU |

The method of 10.5.2 is mainly for the benefit of encoders, and does not solve the latency issue that LIC imposes on decoder pipeline. The problem is that a current block needs to wait for reconstruction of the neighbors, and then it requires a certain number of cycles until the parameters of the linear model are computed. Of particular concern is the fact that many decoder implementations target processing inter and intra coded blocks independently in order to make best benefit of parallel processing. Typically, inter coded blocks of a CTU are decoded first. For this, has a non-negligible complexity impact (in particular for parallel processing) if LIC of an inter coded block uses the reconstruction of intra coded neighbors. If such an approach (disabling LIC from intra coded neighbors, including CPR) would be combined with the approach of 10.5.3 (only using reconstructed inter coded samples from current CTU), the situation would be better, however would still mean that the inter reconstruction within a CTU would need to be sequential (similar as the situation in intra is). Regardless of that, LIC has some additional processing complexity (which doubles in case of bi prediction) which needs to be justified by performance. The processing should also be aligned with the 64x64 VPDU concept. (See further notes on these aspects under M0873.)

Further study was recommended on these aspects.

A BoG (coordinated by C.-W. Hsu and M. Winken) was established to review CE10 related proposals, and suggest candidates for further study in a CE. See the further notes for the discussion of the BoG report JVET-M0873.

(include summaries of contributions from JVET-M0030 subsequently)

[JVET-M0042](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4842) CE10: Uniform Directional Diffusion Filters for Video Coding [J. Rasch, A. Henkel, J. Pfaff, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

[JVET-M0900](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5731) Cross-check of JVET-M0042: CE10: Uniform Directional Diffusion Filters For Video Coding [J. Ström (Ericsson)] [late]

[JVET-M0087](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4890) CE10: Low pipeline latency LIC (test 10.5.2) [K. Abe, T. Toma, J. Li (Panasonic)]

[JVET-M0112](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4917) CE10: LIC confined within current CTU (test 10.5.3) [P. Bordes, T. Poirier, F. Le Léannec (Technicolor)]

[JVET-M0176](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4983) CE10.1.1: Multi-hypothesis prediction for improving non-skip & non-merge inter mode and merge mode [M.-S. Chiang, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0177](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4984) CE10.1.4: Simplification of combined inter and intra prediction [M.-S. Chiang, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0611](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5431) Crosscheck of JVET-M0177 (CE10.1.4: Simplification of combined inter and intra prediction) [B. Wang (Huawei)] [late]

[JVET-M0178](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4985) CE10.2.1: Uni-prediction-based CU-boundary-only OBMC [Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, C.-W. Hsu, C.-C. Chen, Y.-C. Lin, Y.-W. Huang, S.-M. Lei (MediaTek), X. Xiu, Y. He (InterDigital)]

[JVET-M0179](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4986) CE10.2.2: Integer-MV-based CU-boundary-only OBMC [Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, C.-W. Hsu, C.-C. Chen, Y.-C. Lin, Y.-W. Huang, S.-M. Lei (MediaTek), X. Xiu, Y. He (InterDigital)]

[JVET-M0180](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4987) CE10.2.3: Subblock OBMC with uni-prediction-based OBMC at CU boundaries [Y.-C. Lin, C.-C. Chen, C.-W. Hsu, Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0181](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4988) CE10.2.4: Subblock OBMC with integer-MV-based OBMC at CU boundaries [Y.-C. Lin, C.-C. Chen, C.-W. Hsu, Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0189](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4996) CE10.3.1: AMVP mode for triangle prediction [Y. Ahn, D. Sim (Digital Insights)]

[JVET-M0564](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5377) Cross-check of JVET-M0189: CE10.3.1 AMVP mode for triangle prediction [J. Kim, T. Na (SK Telecom), J. Shin, K. Ko (PIXTREE)] [late]

[JVET-M0290](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5097) CE10: Simplification on Combined Inter-Intra Prediction (Test 10.1.3) [W. Xu, B. Wang, H. Yang, J. Chen (Huawei)]

[JVET-M0293](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5100) CE10: Simplification on Combined Inter-Intra Prediction with size restriction (Test 10.1.5) [W. Xu, B. Wang, H. Yang, J. Chen (Huawei), M.-S. Chiang, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0425](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5234) CE10: Multi-hypothesis inter prediction (Test 10.1.2) [M. Winken, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

## CE11: Deblocking (9)

Contributions in this category were discussed Friday 11 Jan. 0900–XXXX (Track B chaired by JRO).

[JVET-M0031](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5564) CE11: Summary Report on Deblocking [A. Norkin, A. M. Kotra]

This contribution provides a summary report of Core Experiment 11 on deblocking filtering. Two categories of proposals are covered by this CE, split into two sub-tests. These sub-tests are 1) long-tap deblocking filters, and 2) deblocking at 4x4 block boundaries.

The proposals were encoded according to two test conditions, which correspond to two anchors.

Anchor-1 is VTM-3.0 according to the CTC [1].

Anchor-2 is VTM-3.0 with ALF switched off (other conditions are the same as in Anchor 2).

|  |  |  |
| --- | --- | --- |
| **Test#** | **Description** | **Document#** |
| 11.1.1 | Very strong deblocking filtering with conditional activation signalling | [JVET-M0092](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4895) |
| 11.1.2 | Extended deblocking filter for luma and chroma | [JVET-M0075](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4878) |
| 11.1.3 | Long deblocking filters (only luma) | [JVET-M0186](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4993) |
| 11.1.4 | CE11: Test results of CE11.1.5 long-tap deblocking filter | [JVET-M0208](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5015) |
| 11.1.5 | Longer tap Luma deblocking filter | [JVET-M0298](file:///C:\hthttp\::phenix.int-evry.fr:jvet:doc_end_user:current_document.php%3fid=5105) |
| 11.1.6 | Combination of JVET-L0403, JVET-L0327, JVET-L0405, JVET-L0140. JVET-L0337, JVET-L0572, JVET-L0072 | [JVET-M0471](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5281) |
| 11.1.7 | Combination of JVET-L0403, JVET-L0327, JVET-L0405, JVET-L0140. JVET-L0337, JVET-L0572, JVET-L0072 with 6 line buffers at CTU boundary | [JVET-M0471](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5281) |
| 11.1.8 | Combination of JVET-L0403, JVET-L0327, JVET-L0405, JVET-L0140. JVET-L0337, JVET-L0572, JVET-L0072 with 4 line buffers at CTU boundary | [JVET-M0471](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5281) |
| 11.2.1 | Deblocking for 4xN, Nx4 blocks and 8xN, Nx8 blocks that are not aligned with 8x8 sample grid | [JVET-M0299](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5106) |
| 11.2.2 | Parallel deblocking filter | [JVET-M0337](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5144) |

Test CE11.1

|  |  |  |
| --- | --- | --- |
| **Tests** | **Luma modified (Y/N)** | **Chroma modified (Y/N)** |
| CE11.1.1 | Y | Y |
| CE11.1.2 | Y | Y |
| CE11.1.3 | Y | N |
| CE11.1.4 | Y | N |
| CE11.1.5 | Y | N |
| CE11.1.6 | Y | Y |
| CE11.1.7 | Y | Y |
| CE11.1.8 | Y | Y |

Luma deblocking complexity

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Tests** | **Samples from block bound. modified** | **Samples from block bound. deblocking decision** | **Max num. oper for filtering per line (add/mult/compar/shift)** | **Max number of oper. for decision per line (add/mult/compar/shift)** | **Num. line buffers** | **Worst case complexity increased (Y/N)** |
| VTM3.0 | 3+3 | 4+4 | 56 (28/2/12/14) | 94 per 8 line segment  11.75 per line | 4 |  |
| CE11.1.1 | M=3+3...16+16 | 1+1 | (2/3/2/1)\*M | 6 (5/0/0/1) per line | 4 | N |
| CE11.1.2 | 7+7 | 8+8 | 246 (138/12/28/68) | 4.5  (12/0/6/0)/4 in additional to VTM | 8 | Y (for filtering) |
| CE11.1.3 | 7+7, 7+3, 3+7, 3+3 | 16 | 266  (168/34/28/36) | 12.5 (24/0/22/4)/4 in addition to VTM | 8 | N |
| CE11.1.4 | 7+7, 3+7 | 16 | 190 (124/12/0/54) | 2.5 (6/0/2/2)/4 in addition to VTM | 4 | N |
| CE11.1.5 | 7+7, 3+7 | 16 | 187(85/4/28/42) | 9 (24/4/4/4)/4 in addition to VTM | 4 | N |
| CE11.1.6 | 7+7, 7+5, 5+7, 5+5, 7+3, 3+7, 5+3, 3+5 | 8+8, 8+6, 6+8, 6+6, 8+4, 4+8, 6+4, 4+6 | 148 (74,24,28,22) | 12 (26/0/10/12)/4 in addition to VTM | 8 | N |
| CE11.1.7 | 7+7, 7+5, 5+7, 5+5, 7+3, 3+7, 5+3, 3+5 | 8+8, 8+6, 6+8, 6+6, 8+4, 4+8, 6+4, 4+6 | 148 (74,24,28,22) | 12 (26/0/10/12)/4 in addition to VTM | 6 | N |
| CE11.1.8 | 7+7, 7+5, 5+7, 5+5, 7+3, 3+7, 5+3, 3+5 | 8+8, 8+6, 6+8, 6+6, 8+4, 4+8, 6+4, 4+6 | 148 (74,24,28,22) | 12 (26/0/10/12)/4 in addition to VTM | 4 | N |

Chroma deblocking complexity

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Tests** | **Samples from block boundary modified** | **Samples from block boundary for deblocking decision** | **Max number of operations for filtering per line (add/mult/compar/shift)** | **Max number of oper. for decision per line (add/mult/compar/shift)** | **Number of line buffers** | **Worst case complexity increased (Y/N)** |
| VTM3.0 | 1+1 | None | 10 (6/0/2/2) | None | 2 |  |
| CE11.1.1 | M=1+1...8+8 | 1+1 | (2/3/2/1)\*M | 6 (5/0/0/1) per line | 2 | Y |
| CE11.1.2 | 3+3 | 4+4 | 56 (28/2/12/14) | 17.5 (19/0/10/6)/2 per line | 4 | Y |
| CE11.1.3 | VTM | VTM | VTM | VTM | 2 | N |
| CE11.1.4 | VTM | VTM | VTM | VTM | 2 | N |
| CE11.1.5 | VTM | VTM | VTM | VTM | 2 | N |
| CE11.1.6 | 3+3 | 4+4 | 76 (48,2,12,14) | 17 (17, 0, 12, 5)/2 per line | 4 | Y |
| CE11.1.7 | 3+3 | 4+4 | 76 (48,2,12,14) | 17 (17, 0, 12, 5)/2 per line | 3 | Y |
| CE11.1.8 | 3+3 | 4+4 | 76 (48,2,12,14) | 17 (17, 0, 12, 5)/2 per line | 2 | Y |

11.1.6-8 are the same (combined from 4 previous proposals) with different mumber of line buffers (8/6/4) at CTU boundary.

11.1.5, 11.1.6-8 use sample-based adaptation of clipping range

It was suggested to translate the maximum number of operations per line into the maximum number of operations per sample (also considering that the long filters are only applied for large blocks), and decode the value “M” of 11.1.1 into a number. Some of the statements in the table above (worst case increased Y/N) may not be true. More detailed analysis is needed but it appears that if proposals increase worst case complexity in terms of number of operations it would not be by a large factor.

This analysis became available in JVET-M0031v4 and was presented in Track B at Friday 18 January 0800 (JRO).

Beyond the number of operations, the number of line buffers is another complexity issue. VTM uses 4 lines for luma and 2 lines for chroma, which is duplicated by some proposals.

Parallel processing capability is given by all proposals at some sufficiently small granularity (though larger than current VVC) – see table below.

|  |  |
| --- | --- |
| **Tests** | **Smallest unit size needed to perform proposed deblocking operations separately from any other units** |
| VTM3.0 | 8x8 |
| CE11.1.1 | luma 16x16, chroma 8x8 (to be verified) |
| CE11.1.2 | 16x16 |
| CE11.1.3 | 16x16 |
| CE11.1.4 | 16x16 |
| CE11.1.5 | 16x16 |
| CE11.1.6 | 32x32 |
| CE11.1.7 | 32x32 |
| CE11.1.8 | 32x32 |

It is however pointed out that some of the proposals 11.1.1-5 did not consider that VTM3 now uses subblock boundary deblocking, whereas the decision of using long filters is based only on CU boundary properties. Therefore, it could happen that a long filter is applied first, and afterwards a subblock boundary within the CU is deblocked again. This would inhibit parallelism. This could be classified as a bug, which however in terms of subjective testing might not be too harmful.

None of the proposals comes with a specification text. For the decision on using long filters, CU and subblock boundaries should be handled equal.

SNR based Results with ALF on

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **AI** | | | | | **RA** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.1.1 | 0.05% | 0.01% | 0.03% | 100% | 100% | 0.35% | 0.12% | 0.12% | 100% | 101% |
| CE11.1.2 | -0.01% | -0.56% | -0.52% | 100% | 102% | -0.06% | -0.41% | -0.32% | 100% | 102% |
| CE11.1.3 | 0.00% | 0.00% | 0.00% | 100% | 101% | -0.02% | -0.02% | 0.00% | 100% | 103% |
| CE11.1.4 | 0.01% | 0.00% | -0.01% | 102% | 103% | 0.00% | 0.01% | 0.00% | 102% | 102% |
| CE11.1.5 | 0.00% | 0.00% | 0.00% | 99% | 100% | 0.02% | -0.01% | 0.00% | 99% | 99% |
| CE11.1.6 | -0.02% | -0.53% | -0.49% | 100% | 99% | 0.00% | -0.80% | -0.82% | 100% | 102% |
| CE11.1.7 | -0.02% | -0.54% | -0.50% | 101% | 99% | -0.01% | -0.82% | -0.85% | 101% | 102% |
| CE11.1.8 | -0.02% | -0.43% | -0.39% | 101% | 103% | 0.00% | -0.71% | -0.68% | 100% | 101% |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **LD-B** | | | | | **LD-P** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.1.1 | 0.40% | 0.20% | 0.15% | 101% | 102% | 0.40% | 0.22% | 0.05% | 101% | 102% |
| CE11.1.2 | 0.03% | 0.53% | 0.23% | 100% | 102% | -0.01% | 0.15% | -0.32% | 100% | 102% |
| CE11.1.3 | 0.01% | -0.02% | 0.00% | 100% | 103% | -0.02% | 0.13% | 0.03% | 100% | 102% |
| CE11.1.4 | 0.13% | -0.03% | -0.09% | 99% | 103% | 0.06% | 0.21% | -0.10% | 101% | 104% |
| CE11.1.5 | 0.13% | 0.15% | 0.07% | 98% | 99% | 0.02% | 0.17% | -0.09% | 98% | 96% |
| CE11.1.6 | 0.13% | -1.32% | -1.58% | 100% | 102% | -0.03% | -1.54% | -1.88% | 100% | 102% |
| CE11.1.7 | 0.12% | -1.38% | -1.48% | 102% | 103% | -0.02% | -1.49% | -1.86% | 101% | 102% |
| CE11.1.8 | 0.08% | -1.15% | -1.42% | 99% | 101% | -0.02% | -1.21% | -1.62% | 101% | 100% |

SNR based results with ALF off

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **AI** | | | | | **RA** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.1.1 | 0.04% | -0.03% | -0.01% | 100% | 101% | 0.36% | 0.09% | 0.07% | 101% | 102% |
| CE11.1.2 | -0.01% | -0.72% | -0.63% | 100% | 102% | -0.09% | -0.45% | -0.36% | 100% | 102% |
| CE11.1.3 | 0.00% | 0.00% | 0.00% | 100% | 102% | -0.01% | 0.00% | 0.00% | 100% | 102% |
| CE11.1.4 | 0.01% | 0.00% | 0.00% | 100% | 102% | -0.03% | -0.08% | -0.03% | 102% | 105% |
| CE11.1.5 | -0.01% | 0.00% | 0.00% | 99% | 100% | 0.00% | -0.03% | 0.03% | 98% | 99% |
| CE11.1.6 | -0.03% | -0.71% | -0.61% | 92%\* | 101% | -0.02% | -0.88% | -0.89% | 84%\* | 103% |
| CE11.1.7 | -0.03% | -0.71% | -0.62% | 108% | 99% | -0.04% | -0.86% | -0.86% | 100% | 102% |
| CE11.1.8 | 0.05% | -1.13% | -1.49% | 104% | 103% | -0.02% | -1.64% | -1.65% | 102% | 103% |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **LD-B** | | | | | **LD-P** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.1.1 | 0.42% | 0.21% | 0.09% | 101% | 102% | 0.42% | 0.13% | 0.13% | 101% | 101% |
| CE11.1.2 | -0.01% | 0.17% | -0.41% | 100% | 102% | -0.09% | -0.43% | -0.61% | 100% | 102% |
| CE11.1.3 | -0.04% | 0.01% | -0.22% | 100% | 102% | 0.00% | -0.04% | 0.02% | 100% | 103% |
| CE11.1.4 | 0.07% | 0.19% | 0.04% | 100% | 105% | 0.01% | 0.09% | 0.02% | 99% | 103% |
| CE11.1.5 | 0.09% | 0.13% | -0.17% | 98% | 98% | -0.06% | 0.10% | -0.14% | 98% | 99% |
| CE11.1.6 | 0.04% | -1.12% | -1.74% | 89%\* | 103% | -0.02% | -1.77% | -1.94% | 81%\* | 102% |
| CE11.1.7 | 0.04% | -1.32% | -1.60% | 105% | 105% | -0.06% | -1.85% | -2.01% | 95% | 104% |
| CE11.1.8 | -0.03% | -0.58% | -0.50% | 104% | 105% | -0.03% | -0.77% | -0.76% | 103% | 103% |

\*Unreliable encoding times.

CE11.2

|  |  |  |
| --- | --- | --- |
| **Test** | **Proponent(s)** | **Cross-checker(s)** |
| CE11.2.1 | Kenneth Andersson [kenneth.r.andersson@ericsson.com](mailto:kenneth.r.andersson@ericsson.com)  Anand Meher Kotra [Anand.meher.kotra@huawei.com](mailto:Anand.meher.kotra@huawei.com)  Chia-Ming Tsai  [chia-ming.tsai@mediatek.com](mailto:chia-ming.tsai@mediatek.com)  [JVET-M0299](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5106) | Hyeongmun Jang  [hm.jang@lge.com](mailto:hm.jang@lge.com) |
| CE11.2.2 | Hyeongmun Jang  [hm.jang@lge.com](mailto:hm.jang@lge.com)  [JVET-M0337](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5144) | Kenneth Andersson [kenneth.r.andersson@ericsson.com](mailto:kenneth.r.andersson@ericsson.com) |

Complexity for luma

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Tests** | **Samples from block bound. modified** | **Samples from block bound. for deblocking decision** | **Max num. oper for filtering per line (add/mult/compar/shift)** | **Max number of oper. for decision per line (add/mult/compar/shift)** | **Num. line buffers** | **Worst case complexity increased (Y/N)** |
| CE11.2.1 | VTM (additional boundary 1+1 but then 1+1 instead of 3+3 for same boundary as VTM) | VTM (additional boundary 3+3 but then 3+3 instead of 4+4 for same boundary as VTM) | VTM (additional boundary 14 (6/2/5/1) but then 14 instead of 56 for same boundary as VTM) | VTM (additional  boundary 20/4  (11/0/5/4) /4 per line but then 20/4 instead of 94/8 for same boundary as VTM) | VTM | N |
| CE11.2.2 | VTM(no filtering on block boundary of 4xN for EDGE\_VER, Nx4 for EDGE\_HOR) | VTM | VTM | VTM | VTM | N |

Complexity for chroma

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Tests** | **Samples from block bound. modified** | **Samples from block bound. for deblocking decision** | **Max num. oper for filtering per line (add/mult/compar/shift)** | **Max number of oper. for decision for 8-sample boundary (add/mult/compar/shift)** | **Num. line buffers** | **Worst case complexity increased (Y/N)** |
| CE11.2.1 | VTM | VTM | VTM | VTM | VTM | N |
| CE11.2.2 | VTM(no filtering on block boundary of 2xN for EDGE\_VER and Nx2 for EDGE\_HOR) | VTM | VTM | VTM | VTM | N |

It is suggested to translate the maximum number of operations per line into the maximum number of operations per sample. This is included in JVET-M0031v4.

VTM3 operates deblocking on an 8x8 grid. If a CU boundary is not on an 8x8 grid, it is not deblocked. If a CU is on an 8x8 grid, furthermore subblocks within that CU are deblocked (provided they are on the 8x8 grid as well). 4xN blocks are deblocked whenever they are coinciding with the 8x8 grid

11.2.1 deblocks on a 4x4 grid, where a boundary is deblocked with VTM filter when the next block or subblock is more than four samples apart, and with a weak and short filter if it is only samples apart.

11.2.2 uses an 8x8 grid and VTM deblocking filter but disables deblocking whenever the boundary would be only four samples apart.

SNR based results (ALF on)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **AI** | | | | | **RA** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.2.1 | 0.02% | 0.00% | 0.00% | 99% | 99% | -0.12% | 0.07% | 0.03% | 98% | 98% |
| CE11.2.2 | -0.09% | 0.22% | 0.15% | 100% | 99% | 0.01% | 0.15% | 0.05% | 100% | 99% |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **LD-B** | | | | | **LD-P** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.2.1 | -0.14% | -0.17% | -0.01% | 98% | 98% | -0.18% | -0.06% | -0.20% | 98% | 98% |
| CE11.2.2 | 0.00% | 0.00% | 0.06% | 100% | 99% | 0.00% | -0.02% | -0.33% | 100% | 100% |

SNR based results (ALF off)

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **AI** | | | | | **RA** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.2.1 | -0.05% | -0.01% | 0.00% | 99% | 99% | -0.23% | -0.02% | -0.04% | 98% | 98% |
| CE11.2.2 | -0.03% | -0.22% | -0.41% | 100% | 100% | 0.08% | 0.18% | 0.15% | 100% | 100% |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Test** | **LD-B** | | | | | **LD-P** | | | | |
| **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** | **Y** | **U** | **V** | **EncT (%)** | **DecT (%)** |
| CE11.2.1 | -0.21% | 0.04% | -0.23% | 98% | 98% | -0.36% | 0.14% | -0.16% | 97% | 98% |
| CE11.2.2 | 0.01% | 0.01% | -0.33% | 100% | 100% | 0.09% | -0.11% | -0.15% | 100% | 100% |

Subjective testing to be done. It is suggested to use an ”AB” comparison where each proposal is compared against VTM3 at same QP.

From the test plan, it would be 96 test cases (2 QPs 34,39, 5 sequences, 8 proposals for 11.1, 2 QPs 30,34, 4 sequences, 2 proposals for 11.2). It would be highly desirable to test both ALF on and ALF off cases. If only one of these cases is possible out of logistic reasons, the ALF off case should be used (as planned in the original CE description). The ALF on bitstreams for subjective testing still need crosscheck.

[JVET-M0906](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5737) Subjective assessment of CE11 (deblocking filter) proposals [V. Baroncini, A. Norkin, A. M. Kotra, K. Andersson, K. Misra, H. Jang, C. M. Tsai, D. Rusanovskyy]

This report was presented in Track B Thu Jan. 17 1200-1330

This contribution provides a report of the subjective test for the proposals in Core Experiment 11 on deblocking filtering. Two set of tests were performed during the Marrakech meeting in accordance with the CE11 description document JVET-L1031. Both tests involved visually evaluating CE proposals versus VTM3 with ALF turned OFF as anchor. ALF was also turned OFF for the CE proposals.

To facilitate further analysis a score representing the number of times the Mean Opinion Score of a CE proposal is better than the anchor, and the anchor lies outside the confidence interval was also computed.

Expert viewing was conducted during the Marrakech meeting for both CE 11.1 (Longer tap filter) category and CE 11.2 (4 x 4 luma sample grid filtering). The sequences and the QP points used are as listed in [2]. The invitation for the subjective viewing participation was issued on the JVET reflector. 12 non-proponent viewers were selected as the test participants for subjective testing for both the categories. All the 12 participants were divided into 4 groups containing 3 participants each.

The dates and the actual timings of the viewing sessions are included with the attached spreadsheets along with the contribution. Each coded video was compared with the anchor; the order of presentation of anchor and coded videos was randomly changed. The Anchor used in all the configurations was with ALF (adaptive loop filter) tool turned off. The coded video also had the ALF (adaptive loop filter) tool turned off.

A video (preceded by the latter A) was shown on the screen, followed a second video (preceded by the letter B); once again A video (preceded by the latter A), followed by the second video (preceded by the letter B) is shown on the screen; then the message “Vote N” was presented asking to the viewers to rate if “A was much better than B”, “A was better than B” or “B was better than A” or “B was much better than A”.

The order of presentation of the video clips inside each test session was assigned randomly taking care not to show the same sequence two consecutive times.

For the CE 11.1 category, following test sequences and conditions were used in the subjective tests. The sequence length is 10 seconds.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Num | Name | Resolution | fps | Frames | Mode | QP |
| 01 | FoodMarket | 3840x2160p | 60fps | 600 | RA | 39, 34 |
| 02 | Campfire | 3840x2160p | 30fps | 300 | RA | 39, 34 |
| 03 | Kimono | 1920x1080p | 24fps | 240 | LDB | 34, 39 |
| 04 | KristenAndSara | 1280x720p | 60fps | 600 | LDP | 34, 39 |
| 05 | Red Kayak\* | 1920x1080p | 30fps | 300 | RA | 34, 39 |

\* First 300 frames of the RedKayak sequence were used.

To facilitate analysis, the scores provided by viewers were translated to a fix scale of 1, 2, 3 or 4, with:

1 representing anchor is much better than a CE proposal,

2 representing anchor is better than a CE proposal,

3 representing a CE proposal is better than the anchor, and

4 representing a CE proposal is much better than the anchor.

The anchor used is VTM3 with ALF OFF. Mean Opinion Score (MOS) and Confidence Intervals (CI) were computed for each data-point. For each QP, these were in turn used to compute:

* Number of times (x) a CE proposal beats the anchor i.e. number of times (MOS – CI) is greater than 2.5; and
* Number of times (y) anchor beats the CE proposal i.e. (MOS + CI) is less than 2.5.

The total score for each CE proposal, for a given QP, is then computed as x – y.

Example illustrating TEST A wins, TEST B tie, TEST C loses for a sequence

From such an approach, it was found that in all cases proposals were either better equal, no case was found worse than the anchors. All tests were performed with “ALF off” anchor. When “ALF on” was compared to “ALF off”, it was also found to be visually better than the anchor in 6 out of 10 test cases, whereas some proposals are better than the anchor in 9 of the test cases, as shown by the following table:

Listed below are the total score of the CE proposals in CE11.1. The attached excel contains more detailed results.**CE11.1**: Long Filters Tests – highest possible total score per QP is +5, lowest possible score per QP is -5:

|  |  |  |
| --- | --- | --- |
| **CE Proposal** | **Total score for QP34** | **Total score for QP39** |
| CE11.1.1 | 2 | 4 |
| CE11.1.2 | 3 | 4 |
| CE11.1.3 | 1 | 2 |
| CE11.1.4 | 2 | 2 |
| CE11.1.5 | 3 | 4 |
| CE11.1.6 | 4 | 5 |
| CE11.1.7 | 2 | 5 |
| CE11.1.8 | 4 | 5 |

One conclusion that can be drawn is that longer-tap deblocking helps for visual quality at large CU boundaries. However, it can not directly be concluded that the effect would still be visible with similar clarity when ALF was on. From looking at scores of individual sequences, it can be seen that some of the ne deblocking with ALF off are still working better than existing deblocking with ALF on in approximately half of the cases, such that it can be concluded that new deblocking methods give a benefit in terms of subjective quality that is additive to the benefit of ALF. Therefore, a conclusion might be drawn that when both new deblocking and ALF were enabled, a visual benefit would still be visible. To investigate if such a statement is true, additional viewing should be done with a selected proposal, one “best performing” (from the table above, where 11.1.8 seems to be the best candidate, as it has good performance and does not increase the need of line buffering). Additional viewing to be performed to confirm that 11.1.8 with ALF on still gives benefit compared to VTM3 with ALF on.

Decision: Adopt JVET-M0471, version 11.1.8 (specification text available in v2 upload, but needs another small modification for restriction of line buffer, was shortly review in track B Thu 1330), pending on confirmation from the viewing, and the more detailed report on complexity impact.

Informal viewing (3 sessions, around 20 participants, 12 of which were not involved in this CE) was conducted Thu 17 Jan evening. It is reported that also in comparison to the ALF on anchor, differences are clearly visible in particular for sequences Campfire, Redkayak, and also slight improvement for Foodmarket and KristenSara.

The complexity analysis in JVET-M0031v4 was presented Fri 18 Jan in Track B. For the adopted proposal, the worst case number of operations is not increased for luma, and the number of line buffers is kept the same. Additional complexity is the need for switching to another filter mode in the case of large blocks, which is not critical. For chroma, the worst case number of operations is increased by approximately 10, as a separate decision is employed. This increase of complexity appears justified by the fact that it gives considerable visual improvement in cases of sequences where chroma is critical.

For CE11.2, results are not as conclusive. A similar analysis as above provides the following table (where in this case, the highest score would be 4):

|  |  |  |
| --- | --- | --- |
| **CE Proposal** | **Total Score for QP30** | **Total Score for QP34** |
| CE11.2.1 | 0 | -1 |
| CE11.2.2 | 0 | 1 |

Compared to that, ALF on versus ALF off has a score of 3 and 2, for QP30 and 34, respectively. This indicates that ALF has a clear benefit over any of the proposals, and it can hardly be concluded that they would further improve the quality when combined. At least in this range of bit rates, deblocking on an aligned 4x4 grid does not seem to improve the visual quality. No action necessary from these results. Could be due to the fact that the design of the CE had a flaw in selecting too low QP range. Might be worthwhile to continue the study now in combination with longer filters, and comparing with ALF on as anchor.

[JVET-M0075](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4878) CE11: Extended Deblocking Filter (test 11.1.2) [K. Unno, K. Kawamura, S. Naito (KDDI)]

[JVET-M0092](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4895) CE11: Very strong deblocking with conditional activation signaling (Test 11.1.1) [C. Helmrich, B. Bross (HHI)]

[JVET-M0186](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4993) 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-M0208](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5015) CE11: long-tap deblocking filter (Test 11.1.4) [W. Choi, K. Choi (Samsung)]

[JVET-M0298](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5105) CE11: Longer tap deblocking filter (test 11.1.5) [A. M. Kotra, B. Wang, S. Esenlik, H. Gao, J. Chen (Huawei)]

[JVET-M0299](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5106) CE11: Deblocking for 4 x N, N x 4 blocks and 8 x N, N x 8 blocks that are not aligned with 8 x 8 sample grid (test 11.2.1) [K. Andersson, Z. Zhang, R. Sjöberg (Ericsson), A. M. Kotra, J. Chen, S. Esenlik, B. Wang, H. Gao (Huawei), C.-M. Tsai, C.-W. Hsu, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0337](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5144) CE11: Test CE11.2.1 Parallel deblocking filter [H. Jang, J. Nam, S. Kim, J. Lim (LGE)]

[JVET-M0471](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5281) CE11.1.6, CE11.1.7 and CE11.1.8: Joint proposals for long deblocking from Sony, Qualcomm, Sharp, Ericsson [M. Ikeda, T. Suzuki (Sony), D. Rusanovskyy, M. Karczewicz (Qualcomm), W. Zhu, K. Misra, P. Cowan, A. Segall (Sharp Labs of America), K. Andersson, J. Enhorn, Z. Zhang, R. Sjöberg (Ericsson)]

## CE12: Mapping functions (2)

Contributions in this category were discussed Saturday 12 Jan. 1600–1645, 1700-1800 (chaired by GJS).

[JVET-M0032](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5538) CE12: Summary report on mapping functions [E. François, P. Yin]

This contribution provides a summary report of Core Experiment 12 on mapping functions. CE12 evaluates approaches for mapping of HDR and SDR content, with main focus on SDR. The considered technologies are in-loop reshaping and related variants. Test results against VTM3.0 anchors are provided for each performed test. Crosschecking reports are integrated in this contribution.

CE12-1: In-loop Reshaping for SDR on coding efficiency (JVET-L0247)

|  |  |  |  |
| --- | --- | --- | --- |
| Test | Proponent | Description | Xchecker |
| CE12-1 | Dolby  (JVET-L0247) | Test in-loop reshaping for SDR focused on coding efficiency improvement, such as making reshaping function rate adaptive, disable towards higher rates. | E. François (Technicolor) |

In JVET-L0247, the reshaper has two main components: 1) in-loop reshaping applied to the luma component; 2) additional luma-dependent chroma residue scaling applied to chroma components.

The two elements had been tested separately (see JVET-K0308) and it had been concluded that the two should be tested together.

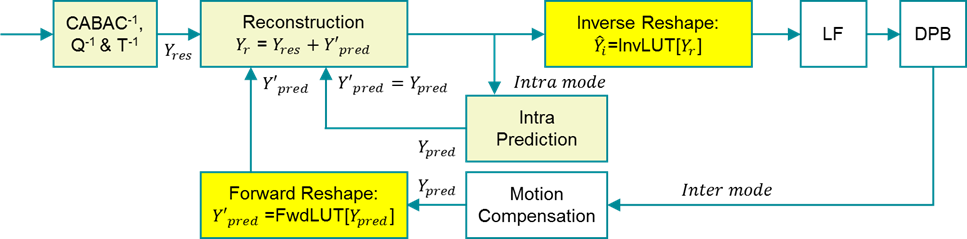
CE12-1 was testing a method proposed at the previous meeting with some encoder improvement. However, a somewhat different method had been developed since then, and there was no longer any interest in considering the CE12-1 scheme.

CE12-2: In-loop Reshaping for SDR on In-loop Reshaping for SDR on implementation investigation

|  |  |  |  |
| --- | --- | --- | --- |
| Test | Proponent | Description | Xchecker |
| CE12-2 | Dolby  (JVET-L0247) | Test in-loop reshaping for SDR focused on implementation investigation on pipelining of the block-wise prediction loop: such as piece-wise linear interpolation replacing LUT-based mapping, disable intra-block in inter slices. | J. Xu (ByteDance),  E. François (Technicolor) |

**In-loop luma reshaping:** CE12-2 tests a lower complexity pipeline that also eliminates decoding latency for block-wise intra prediction in inter slice reconstruction. Intra prediction is performed in reshaped domain for both inter and intra slices.

CE12-2 also tests 16-piece PWL models for luma and chroma residue scaling instead of the 32-piece PWL models of CE12-1.



Inter slice reconstruction with in-loop luma reshaper in CE12-2 (light-green shaded blocks indicate signal in reshaped domain: luma residue; intra luma predicted; and intra luma reconstructed)

**Luma-dependent chroma residue scaling** is a multiplicative process implemented with fixed-point integer operation. Chroma residue scaling compensates for luma signal interaction with the chroma signal. Chroma residue scaling is applied at the TU level.

For intra the reconstructed luma is averaged

For inter, the prediction luma is averaged.

The average is used to identify an index in a PWL model. The index identifies a scaling factor cScaleInv.

The chroma residual is multiplied by that number.

[A modified diagram including chroma processing was provided in a revision of M0427 - include.]

BD-rate of CE12-1 and CE12-2 for SDR

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **All Intra** | psnrY | psnrU | psnrV | EncT | DecT |
| 12-1 | -0.89% | 1.52% | 1.15% | 103% | 100% |
| 12-2 | -0.89% | 1.49% | 1.18% | 102% | 101% |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Random Access** | psnrY | psnrU | psnrV | EncT | DecT |
| 12-1 | -1.28% | 0.53% | 0.52% | 105% | 101% |
| 12-2 | -1.30% | 1.45% | 1.44% | 105% | 104% |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Low Delay B** | psnrY | psnrU | psnrV | EncT | DecT |
| 12-1 | -0.72% | 0.46% | 0.11% | 100% | 101% |
| 12-2 | -0.76% | 1.78% | 1.42% | 98% | 105% |

The parameters are (currently) sent in the tile group header (similar to ALF). These reportedly take 40-100 bits.

Suggestions for easing implementation were:

* Disabling the chroma residual scaling for separate tree operation
* Disabling the chroma residual scaling for 2x2 chroma
* Using the prediction signal rather than the reconstruction signal for intra as well as inter

The proponent indicated that these suggestions had previously been tested and should not affect the performance, and said test results would be provided in a revision of their contribution M0427.

It was noted that in the current CTC, separate trees are used for intra slices.

It was noted that some loss was observed for the chroma, although the luma gain was enough to more than compensate for that.

A participant commented that there could be rate allocation effects that could be achieved by local delta QP or setting of QP based on temporal layer. It was remarked that some tests along those lines were reported in L0246. In L0246 some gain was reported in class B but not class A and not as much as for using this technique. Rate-distortion optimized local QP selection (e.g., testing +/1 values of QP) was one suggested way to get improvement using local QP adjustment.

As used, the PWL mapping uses 16 equal size segments for the forward mapping, so determining the index is just a shift. For the inverse mapping, though, it is not using equal spacing. There are two contributions related to this, M0640 which tries to simplify the index determination and M0109 to make the scale factor for the luma processing be determined on a 4x4 basis instead of on a per-sample basis.

The spec would be written that CPR is not affected; the prediction signal in that case does not go through the special processing.

Revisit for review of test results. [Resolved per notes elsewhere]

[JVET-M0427](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5236) CE12: Mapping functions (test CE12-1 and CE12-2) [T. Lu, F. Pu, P. Yin, W. Husak, S. McCarthy, T. Chen (Dolby)]

## CE13: Coding tools for 360° omnidirectional video (11)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

[JVET-M0033](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5466) CE13: Summary report on coding tools for 360° omnidirectional video [P. Hanhart, J.-L. Lin, C. Pujara]

[JVET-M0143](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4950) CE13: Face row based geometry padding using projection with bilinear interpolation based on test 1.1.a (Test 2.1.b) [P. Hanhart, Y. He (InterDigital)]

[JVET-M0144](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4951) CE13: Adaptive frame packing based on test 1.1.a (Test 4.1) [P. Hanhart, Y. He (InterDigital)]

[JVET-M0235](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5042) CE13: HEC with Pre-rotation based on test 1.1a and 1.1b (Test 4.2) [C. Pujara, A. Konda, A. Singh, R. Gadde, W. Choi, K. Choi, K.P. Choi (Samsung)] [late]

[JVET-M0320](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5127) CE13: HEC with deblocking using spherical neighbors, SAO and ALF disabled across face discontinuities (Test 1.4) [X. Huangfu, Y. Sun, L. Yu (Zhejiang Univ.)] [late]

[JVET-M0321](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5128) CE13: Post-filtering of seam artifacts based on test 1.1.a (Test 3.1) [X. Huangfu, Y. Sun, L. Yu (Zhejiang Univ.)] [late]

[JVET-M0355](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5163) CE13: Results on CE13.2.2 and CE13.5.2 [J. Sauer, M. Bläser (RWTH Aachen University)]

[JVET-M0362](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5169) CE13: In-loop filters disabled across face discontinuities (Test 1.1.a and Test1.1.b) [S.-Y. Lin, L. Liu, J.-L. Lin, Y.-C. Chang, C.-C. Ju (MediaTek), P. Hanhart, Y. He (InterDigital)]

[JVET-M0363](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5170) CE13: HEC with in-loop filters using spherical neighbors (Test 1.3) [S.-Y. Lin, L. Liu, J.-L. Lin, Y.-C. Chang, C.-C. Ju (MediaTek)]

[JVET-M0364](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5171) CE13: Test 1.1.a with face row based geometry padding of reference pictures (Test 2.1.a, Test 2.1.c and Test 2.1.d) [C.-H. Shih, J.-L. Lin, Y.-C. Chang, C.-C. Ju (MediaTek)]

[JVET-M0367](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5174) CE13: Face row based geometry padding of reference pictures and in-loop filters using spherical neighbors (Test 5.1) [C.-H. Shih, S.-Y. Lin, L. Liu, J.-L. Lin, Y.-C. Chang, C.-C. Ju (MediaTek)]

# Non-CE Technology proposals

## CE1 related – Partitioning (6)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

[JVET-M0195](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5002) CE1-related: Non-Residual Block on VPDU Boundary [A. Tamse, M. W. Park, M. Park, K. Choi (Samsung)]

Discussed elsewhere in notes.

[JVET-M0630](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5450) Crosscheck of JVET-M0195 (CE1-related: Non-Residual Block on VPDU Boundary) [C. Rosewarne (Canon)] [late]

[JVET-M0237](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5044) CE1-related: Transform tiling with residual reordering for pipelined processing of CTUs [C. Rosewarne, A. Dorrell (Canon)]

Discussed elsewhere in notes.

[JVET-M0285](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5092) CE1-related: Prediction Mode Restriction and Implicit Transform Splitting to Enable VPDU [Y. Zhao, S. Esenlik, H. Yang, J. Chen (Huawei)]

Discussed elsewhere in notes.

[JVET-M0628](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5448) Crosscheck of JVET-M0285 (CE1-related: Prediction Mode Restriction and Implicit Transform Splitting to Enable VPDU) [C. Rosewarne (Canon)] [late]

[JVET-M0421](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5230) Non-CE1: Split-first signalling for partitioning [A. Wieckowski, T. Nguyen, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

Presented Thu 8pm. Chaired by FJB

In the current draft of VVC, the partitioning is a straightforward extension of the HEVC partitioning approach. At the CTU level, a quad-split (QT) flag is signalled indicating whether a square block should be split into four equally sized square blocks. Once no further quad-split is signalled, a binary-and-ternary tree (BTT) is signalled, for which the splits are signaled more extensively using up to three flags, indicating if a block should be split, in which direction it should be split, and if a ternary or binary split is to be performed. If a block should not be split, it is required to signal up to two flags indicating that neither a QT nor BTT split is to be performed. The proposed approach in this document adapted signalling in which a single flag indicates if a block should be split, followed by coding of the split mode. The proposed adaptation of split binarization, together with adapted context modelling introduces AI/RA/LB/LP luma BD-rate gains of -0.03/-0.07/-0.06/-0.05.

Two additional contexts compared to VTM3.

Allowable partitions remain the same. Only encoding changes.

Main benefit is simplified and cleaner text.

Decision: adopt

[JVET-M0780](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5611) Crosscheck of JVET-M0421 (Non-CE1: Split-first signalling for partitioning) [Y. Yasugi, T. Ikai (Sharp)] [late]

[JVET-M0888](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5719) CE1-related: Picture boundary handling with VPDU constraints [C.-M. Tsai, S.-T. Hsiang, C.-W. Hsu, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)] [late]

Discussed Thu 1515

Two approaches are proposed for changing the handling at the picture boundaries so that VPDUs are the same at picture boundaries as within the picture. This proposes inferred splits at picture boundaries. One approach uses an inferred QT split (0.06% penalty in RA, higher penalty in Class E); another uses a signalled choice between QT split and a BT split perpendicular to the picture boundary (0.05% penalty in RA).

[JVET-M0897](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5728) Crosscheck of JVET-M0888 (CE1-related: Picture boundary handling with VPDU constraints) [Y.-W. Chen (Kwai Inc.)] [late]

[JVET-M0905](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5736) CE1-related: Picture Boundary Handling regarding to VPDU [H. Gao, S. Esenlik, B. Wang, A.M. Kotra, J. Chen (Huawei)] [late]

Discussed Thu 1515

This is the same as the first approach in M0888.

## CE2 related – Subblock motion compensation (31)

Contributions in this category were discussed in BoG JVET-M0862 unless otherwise noted.

[JVET-M0049](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4851) CE2-related: A restriction on memory bandwidth consumption of affine mode [M. Zhou (Broadcom)]

[JVET-M0441](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5250) Crosscheck of JVET-M0049 (CE2-related: A restriction on memory bandwidth consumption of affine mode) [K. Zhang (Bytedance)] [late]

[JVET-M0110](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4915) CE2-related: Alignment of affine control-point motion vector and subblock motion vector [H. Huang, W.-J. Chien, V. Seregin, H. Wang, M. Karczewicz (Qualcomm)]

[JVET-M0747](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5578) Crosscheck of JVET-M0110 Test 2 (CE2-related: Alignment of affine control-point motion vector and subblock motion vector) [J. Luo (InterDigital)] [late]

[JVET-M0737](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5568) Crosscheck of JVET-M0110 (CE2-related: Alignment of affine control-point motion vector and subblock motion vector) [A. Tamse (Samsung)] [late]

[JVET-M0598](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5417) Crosscheck of JVET-M0110 (CE2-related: Alignment of affine control-point motion vector and subblock motion) [T. Zhou, T. Ikai (Sharp)] [late]

[JVET-M0116](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4921) CE2-related: ATMVP simplification [R. Yu, D. Liu, K. Andersson, R. Sjöberg (Ericsson)]

[JVET-M0460](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5269) Crosscheck of JVET-M0116 (CE2-related: ATMVP simplification) [L. Zhang (Bytedance)] [late]

[JVET-M0145](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4952) Non-CE2: Motion vector clipping in affine sub-block motion vector derivation [P. Hanhart, Y. He (InterDigital)]

[JVET-M0735](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5565) Crosscheck of JVET-M0145 (Non-CE2: Motion vector clipping in affine sub-block motion vector derivation) [H. Chen (Huawei)] [late]

[JVET-M0166](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4973) CE2-related: Simplification of constructed affine merge candidate derivation [Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0575](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5389) Crosscheck of JVET-M0166 (CE2-related: Simplification of constructed affine merging candidate derivation) [Y. He (InterDigital)] [late]

[JVET-M0167](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4974) CE2-related: Decoupling of SbTMVP and affine merge candidate derivation in subblock merge mode [Y.-L. Hsiao, T.-D. Chuang, C.-W. Hsu, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0850](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5681) Cross-check of JVET-M0167 (CE2-related: Decoupling of SbTMVP and affine merge candidate derivation in subblock merge mode) [S. Sethuraman (Ittiam)] [late]

[JVET-M0168](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4975) CE2-related: Simplifications for inherited affine candidates [Y.-L. Hsiao, T.-D. Chuang, C.-W. Hsu, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0720](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5547) Crosscheck of JVET-M0168 (CE2-related: Simplifications for inherited affine candidates) [H. Chen, T. Solovyev (Huawei)] [late]

[JVET-M0192](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4999) CE2-related: MV Derivation for Affine Chroma [A. Tamse, M. W. Park, K. Choi (Samsung)]

[JVET-M0603](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5422) Crosscheck of JVET-M0192 (CE2-related: MV Derivation for Affine Chroma) [G. Li (Tencent)] [late]

[JVET-M0204](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5011) CE2-related: Simplification of ATMVP [M. Park, M. W. Park, S. Jeong, A. Tamse, K. Choi (Samsung)]

[JVET-M0594](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5413) Crosscheck of JVET-M0204 (CE2-related: Simplification of ATMVP) [T. Zhou, T. Ikai (Sharp)] [late]

[JVET-M0217](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5024) CE2-related: Constructed affine merge candidate simplification [L. Li, J Nam, N Park, H Jang, J Lim, S Kim (LGE)]

[JVET-M0719](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5546) Crosscheck of JVET-M0217 (CE2-related: Constructed affine merge candidate simplification) [H. Chen (Huawei)] [late]

[JVET-M0228](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5035) CE2-related: Affine mode simplifications [Y.-W. Chen, X. Wang (Kwai Inc.)]

[JVET-M0601](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5420) Crosscheck of JVET-M0228 (CE2-related: Affine mode simplifications) [T.-S. Chang, Y.-C. Sun, J. Lou (Alibaba)] [late]

[JVET-M0240](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5047) CE2-related: Simplification of subblock-based temporal merging candidates [H. Lee, S.-C. Lim, J. Lee, J. Kang, H. Y. Kim (ETRI)]

[JVET-M0620](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5440) Crosscheck of JVET-M0240 (CE2-related: Simplification of subblock-based temporal merging candidates) [Y.-W. Chen (Kwai Inc.)] [late]

[JVET-M0247](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5054) CE2 related: Joint test of AMVR for Affine Inter mode (Test 2.1.1 and Test 2.1.2) [H. Liu, K. Zhang, L. Zhang, J. Xu (Bytedance), D. Luo, Y. He, X. Xiu (InterDigital)]

[JVET-M0863](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5694) Crosscheck of JVET-M0247 (CE2-related: Joint Test of AMVR for Affine Inter Mode (Test 2.1.1 and Test 2.1.2)) [K. Choi] [late]

[JVET-M0266](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5073) CE2-related: History-based affine merge candidates [K. Zhang, L. Zhang, H. Liu, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-M0662](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5483) Crosscheck of JVET-M0266 (CE2-related: History-based affine merge candidates) [R.-L. Liao, C. S. Lim (Panasonic)] [late]

[JVET-M0268](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5075) Non-CE2: Interweaved Prediction for Affine Motion Compensation [K. Zhang, L. Zhang, H. Liu, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-M0744](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5575) Crosscheck of JVET-M0268 (Non-CE2: Interweaved Prediction for Affine Motion Compensation) [J. Luo (InterDigital)] [late]

[JVET-M0270](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5077) CE2-related: An alternative storing method for affine inheritance [K. Zhang, L. Zhang, H. Liu, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-M0572](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5385) Crosscheck of JVET-M0270 (CE2-related: An alternative storing method for affine inheritance) [G. Li (Tencent)] [late]

[JVET-M0273](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5080) CE2-related: Early awareness of accessing temporal blocks in sub-block merge list construction [L. Zhang, K. Zhang, H. Liu, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-M0531](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5342) Crosscheck of JVET-M0273 (CE2-related: Early awareness of accessing temporal blocks in sub-block merge list construction) [R. Yu (Ericsson)] [late]

[JVET-M0310](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5117) CE2-related: Using shorter-tap filter for 4x4 sized partition [J. Li, R.-L. Liao, C. S. Lim (Panasonic)]

[JVET-M0827](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5658) Crosscheck of JVET-M0310 (CE2-related: Using shorter-tap filter for 4x4 sized partition) [Y.-C. Lin (MediaTek)] [late]

[JVET-M0311](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5118) CE2-related: Memory bandwidth reduction for affine mode with less dependency [J. Li, R.-L. Liao, C. S. Lim (Panasonic)]

This presented in Track B Tue 15 January 1210

This contribution is a further simplification on JVET-M0309. In this contribution, the first control point is used instead of first sub-block’s motion vector as center of motion vector constrained region of affine mode.

the BD-rate difference is 0.03% in RA, 0.01% in LD\_B respectively.

Further study.

[JVET-M0622](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5442) Crosscheck of JVET-M0311 (CE2-related: Memory bandwidth reduction for affine mode with less dependency) [Y.-W. Chen (Kwai Inc.)] [late]

[JVET-M0338](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5145) Non-CE2: Simplified derivation process for SbTMVP [H. Jang, J. Nam, S. Kim, J. Lim (LGE)]

[JVET-M0535](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5347) Crosscheck of JVET-M0338 (Non-CE2: Simplified neighboring spatial coding unit derivation for SbTMVP) [R. Yu (Ericsson)] [late]

[JVET-M0343](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5150) Non-CE2: Simplified derivation process for SbTMVP [H. Jang, J. Nam, S. Kim, J. Lim (LGE)]

[JVET-M0690](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5512) Cross check of JVET-M0343 [K. Misra (Sharp Labs of America)] [late]

[JVET-M0382](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5189) CE2-related: Modification of Triangle and MMVD merge indexes coding [G. Laroche, C. Gisquet, P. Onno, J. Taquet (Canon)]

[JVET-M0560](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5373) Crosscheck of JVET-M0382 (CE2-related: Modification of Triangle and MMVD merge indexes coding) [H. Lee, S.-C. Lim, J. Lee, J. Kang (ETRI)] [late]

[JVET-M0400](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5208) CE2-related: Worst-case memory bandwidth reduction for VVC [W.-J. Chien, L. Pham Van, H. Huang, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-M0665](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5486) Crosscheck of JVET-M0400 [S. Jeong, K. Choi (Samsung)] [late]

[JVET-M0406](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5214) CE2/4-related: Unified merge list size for block and sub-block merge modes [X. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0576](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5390) Crosscheck of JVET-M0406 (CE2/4-related: Unified merge list size for block and sub-block merge modes) [C.-Y. Lai (MediaTek)] [late]

[JVET-M0432](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5241) CE2-related: Combination of CE2.2.3.d and affine inheritance from motion data line buffer [G. Li, X. Xu, X. Li, S. Liu (Tencent), J. Zhao, S. Kim (LGE)]

[JVET-M0740](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5571) Crosscheck of JVET-M0432 (CE2-related: Combination of CE2.2.3.d and affine inheritance from motion data line buffer) [A. Tamse (Samsung)] [late]

[JVET-M0434](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5243) CE2-related: Constraint on constructed affine merge candidates [G. Li, X. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0546](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5359) Crosscheck of JVET-M0434 (CE2-related: Constraint on constructed affine merge candidates) [L. Zhang (Bytedance)] [late]

[JVET-M0462](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5271) CE2-related: 4x4 chroma affine motion compensation and motion vector rounding unification [L. Pham Van, W.-J. Chien, H. Huang, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-M0859](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5690) Crosscheck of JVET-M0462: CE2-related: 4x4 chroma affine motion compensation and motion vector rounding unification [X. Zheng, Y. Wang (DJI)] [late]

[JVET-M0467](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5277) CE2-related: Symmetric MVD for Affine Bi-prediction Coding [J. Luo, Y. He (InterDigital)]

[JVET-M0795](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5626) Crosscheck of JVET-M0467 (CE2-related: Symmetric MVD for Affine Bi-prediction Coding) [C.-C. Chen, W.-J. Chien (Qualcomm)] [late]

[JVET-M0490](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5300) CE2-related: Simplified context model for triangular prediction mode [M. Gao, X. Li, S. Liu (Tencent)]

[JVET-M0753](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5584) Crosscheck of JVET-M0490 (CE2-related: Simplified context model for triangular prediction mode) [R.-L. Liao, C. S. Lim (Panasonic)] [late]

[JVET-M0515](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5326) Non-CE2.5: ATMVP Collocated Block Derivation from History-based Candidate [C.-C. Chen, W.-J. Chien, Y. Zhang, C.-H. Hung, Y. Han, H. Huang, M. Karczewicz (Qualcomm)]

[JVET-M0746](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5577) Crosscheck of JVET-M0515 (Non-CE2.5: ATMVP Collocated Block Derivation from History-based Candidate) [J. Luo (InterDigital)] [late]

[JVET-M0526](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5337) CE2-related: Further simplification of ATMVP collocated block derivation [S.H. Wang (Peking University), X. Zheng (DJI), S.S. Wang, S.W. Ma (Peking University)] [late]

Initial upload rejected as placeholder

[JVET-M0602](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5421) Cross-check of JVET-M0526: CE2-related: Further simplification of ATMVP collocated block derivation [S. Bandyopadhyay (InterDigital)] [late]

[JVET-M0702](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5524) CE2-related: Adaptive sub-block MV clip for affine blocks [X. Li, M. Gao, S. Liu (Tencent)] [late]

[JVET-M0756](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5587) CE2.2.7 related: Affine temporal constructed candidates without pruning [F. Galpin, A. Robert, F. Le Léannec, T. Poirier (Technicolor)] [late]

[JVET-M0812](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5643) Crosscheck of JVET-M0756: CE2.2.7 related: Affine temporal constructed candidates without pruning [L. Pham Van, G. Van der Auwera, H. Huang, M. Karczewicz (Qualcomm)] [late]

[JVET-M0839](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5670) CE2-related: On number of fast merge candidates for Affine Merge mode [A. Robert, F. Le Léannec, F. Galpin (Technicolor)] [late]

[JVET-M0889](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5720) Crosscheck of JVET-M0839 (CE2-related: On number of fast merge candidates for Affine Merge mode) [Y.-W. Chen (Kwai Inc.)] [late]

## CE3 related – Intra prediction and mode coding (44)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

See also JVET-M0203 which contains a new proposal called 3.5.1 that was not part of the CE.

See also section 7.

[JVET-M0044](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4845) Non-CE3: Alternative LM Chroma Implementation [S. Keating, K. Sharman (Sony)]

[JVET-M0047](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4849) Non-CE3: Intra Angular Prediction and Modified PDPC Based on Two Reference Lines [D. Jiang, J. Lin, F. Zeng, C. Fang (Dahua)]

[JVET-M0048](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4850) Non-CE3: Modified Chroma Derived Mode [F. Zeng, J. Lin, D. Jiang, C. Fang (Dahua)]

[JVET-M0064](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4866) Non-CE3: CCLM table reduction and bit range control [Y. Yasugi, F. Bossen, E. Sasaki (Sharp)]

[JVET-M0548](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5361) Crosscheck of JVET-M0064 (Non-CE3: CCLM table reduction and bit range control) [C.-M. Tsai (MediaTek)] [late]

[JVET-M0093](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4896) Non-CE3: Improved robustness for calculation of cross-component linear model parameters [C. Helmrich (HHI)]

[JVET-M0095](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4899) Non-CE3: Intra simplifications [G. Van der Auwera, A. K. Ramasubramonian, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-M0676](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5497) Crosscheck of JVET-M0095 (Non-CE3: Intra simplifications) [P. Merkle (HHI)] [late]

[JVET-M0099](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4904) Non-CE3: Partial sorting for non-MPM modes [A. K. Ramasubramonian, G. Van der Auwera, T. Hsieh, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-M0658](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5479) Crosscheck of JVET-M0099 (Non-CE3: Partial sorting for non-MPM modes) [K. Choi (Samsung)] [late]

[JVET-M0100](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4905) CE3-related: DM-dependent chroma intra prediction modes [G. Rath, F. Urban, F. Racapé (Technicolor)]

[JVET-M0439](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5248) Crosscheck of JVET-M0100 (CE3-related: DM-dependent chroma intra prediction modes) [H. Liu (Bytedance)] [late]

[JVET-M0108](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4913) CE3-related: Reducing the number of reference samples and table size in LM Chroma process [E. François, T. Poirier, F. Le Léannec (Technicolor)]

[JVET-M0571](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5384) Crosscheck of JVET-M0108 (CE3-related: Reducing the number of reference samples and table size in LM Chroma process) [L. Zhang (Bytedance)] [late]

[JVET-M0643](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5463) Crosscheck of JVET-M0108 (CE3-related: Reducing the number of reference samples and table size in LM Chroma process) [P. Hanhart (InterDigital)] [late]

[JVET-M0138](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4945) Non-CE3: Intra reference sample deblocking [Z. Zhang, K. Andersson, R. Sjöberg (Ericsson)]

[JVET-M0550](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5363) Crosscheck of JVET-M0138 (Non-CE3: Intra reference sample deblocking) [C.-M. Tsai (MediaTek)] [late]

[JVET-M0139](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4946) Non-CE3: History-based intra most probable modes derivation [Z. Zhang, P. Wennersten, R. Yu, J. Ström, R. Sjöberg (Ericsson)]

[JVET-M0639](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5459) Crosscheck of JVET-M0139 (Non-CE3: History-based intra most probable modes derivation) [B. Wang (Huawei)] [late] [missing at end of meeting]

[JVET-M0443](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5252) Crosscheck of JVET-M0139 (Non-CE3: History-based intra most probable modes derivation) [J. Li, L. Zhang (Bytedance)] [late]

[JVET-M0146](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4953) Non-CE3: MDLM template downsampling [P. Hanhart, Y. He (InterDigital)]

[JVET-M0733](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5562) Crosscheck of JVET-M0146 (Non-CE3: MDLM template downsampling) [C. Chevance (Technicolor)] [late]

[JVET-M0149](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4954) Non-CE3: On simplification of PDPC basic equation [A. Filippov, V. Rufitskiy, J. Chen (Huawei)]

[JVET-M0677](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5499) Crosscheck of JVET-M0149 (Non-CE3: simplification of PDPC basic equation) [F. Racapé (Technicolor)] [late]

[JVET-M0158](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4965) Non-CE3: LUT-free interpolation filters for intra prediction [A. Filippov, V. Rufitskiy, J. Chen (Huawei)]

[JVET-M0805](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5636) Cross-check of contribution JVET-M0158 (Non-CE3: LUT-free interpolation filters for intra prediction) [M. Schäfer, J. Pfaff (HHI)] [late]

[JVET-M0680](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5502) Crosscheck of JVET-M0158 (Non-CE3: LUT-free interpolation filters for intra prediction) [F. Racapé (Technicolor)] [late]

[JVET-M0191](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4998) CE3-related: Construction of non-MPM mode list in intra prediction [S. Cha, G. Lee, G. Kim, J. Han (Sejong University)]

[JVET-M0242](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5049) Crosscheck of JVET-M0191 (CE3-related: Construction of non-MPM mode list in intra prediction) [J. Lee, H. Lee, S.-C. Lim, J. Kang (ETRI)] [late]

[JVET-M0210](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5017) Non-CE3: Intra prediction information coding [J. Yao, J. Zhu, W. Cai, K. Kazui (Fujitsu)]

[JVET-M0758](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5589) Crosscheck of JVET-M0210 (Non-CE3: Intra prediction information coding) [C.-C. Kuo, C.-H. Yau, C.-C. Lin (ITRI)] [late]

[JVET-M0211](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5018) CE3-related: Fixed Reference Samples Design for 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-M0716](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5540) Crosscheck of JVET-M0211 (CE3-related:Fixed Reference Samples Design for CCLM) [X. Ma (Huawei)] [late]

[JVET-M0212](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5019) CE3-related: Improved reference samples range for MDLM [S. Wan (NPU), Q.-H.Ran, X.-W. Li, Y.-Z. Ma, J.-Y. Huo, F.-Z. Yang (Xidian Univ.), Y.-F. Yu, Y. Liu (OPPO)]

[JVET-M0717](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5541) Crosscheck of JVET-M0212 (CE3-related:Improved reference samples range for MDLM) [X. Ma (Huawei)] [late]

[JVET-M0213](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5020) CE3-related: Chroma intra candidates modification based on directional DM [Y.-Z. Ma, J.-L. Wang, X.-W. Li, J.-Y. Huo, F.-Z. Yang (Xidian Univ.), S. Wan (NPU), Y.-F. Yu, Y. Liu (OPPO)]

[JVET-M0718](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5542) Crosscheck of JVET-M0213 (CE3-related: Chroma intra candidates modification based on directional DM) [X. Ma (Huawei)] [late]

[JVET-M0214](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5021) CE3-related: Uniform Chroma intra candidates modification based on DM [Y.-Z. Ma, X.-W. Li, J.-L. Wang, J.-Y. Huo, F.-Z. Yang (Xidian Univ.), S. Wan (NPU), Y.-F. Yu, Y. Liu (OPPO)]

[JVET-M0219](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5026) 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-M0586](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5403) Crosscheck of JVET-M0219 (CE3-related: Reduced number of reference samples for CCLM parameter calculation) [K. Zhang (Bytedance)] [late]

[JVET-M0229](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5036) CE3-related: Simplification of LM Mode [[Y.-W. Chen](mailto:yiwenchen@kwai.com), [X. Wang (Kwai Inc.)](mailto:xianglinwang@kwai.com)]

[JVET-M0632](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5452) Crosscheck of JVET-M0229 (CE3-related: Simplification of LM Mode) [K. Abe (Panasonic)] [late]

[JVET-M0239](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5046) Non-CE3: Modification of MPM derivation [J. Lee, H. Lee, S.-C. Lim, J. Kang, H. Y. Kim (ETRI)]

[JVET-M0609](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5429) Crosscheck of JVET-M0239 (Non-CE3: Modification of MPM derivation) [B. Wang (Huawei)] [late] [missing at end of meeting]

[JVET-M0258](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5065) CE3-related: Chroma intra candidates modification based on non-directional DM [J.-Y. Huo, J.-L. Wang, X.-W. Li, Y.-Z. Ma, F.-Z. Yang (Xidian Univ.), S. Wan (NPU), Y.-F. Yu, Y. Liu (OPPO)]

[JVET-M0274](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5081) CE3-related: Modified linear model derivation for CCLM modes [M. Wang, K. Zhang, L. Zhang, H. Liu, J. Xu, S. Wang (Bytedance), J. Li, S. Wang, W. Gao (Peking University)]

[JVET-M0641](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5461) Crosscheck of JVET-M0274 (CE3-related: Modified linear model derivation for CCLM modes) [E. François (Technicolor)] [late]

[JVET-M0295](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5102) CE3-related: Harmonization of MPM list construction [B. Wang, S. Esenlik, A.M. Kotra, H. Gao, J. Chen (Huawei)]

[JVET-M0865](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5696) Crosscheck of JVET-M0295 (CE3-related: Harmonization of MPM list construction) [L Li (LGE)] [late]

[JVET-M0324](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5131) CE3-related: Modified Chroma Intra Mode Coding [J. Park, B. Jeon (SKKU)]

[JVET-M0818](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5649) Crosscheck of JVET-M0324 (CE3-related: Modified Chroma Intra Mode Coding) [L. Zhang (Bytedance)] [late]

[JVET-M0356](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5162) CE3-related: simplified calculation for CCLM parameters derivation [A. Filippov, X. Ma, V. Rufitskiy, H. Yang, J. Chen (Huawei)]

[JVET-M0679](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5501) Crosscheck of JVET-M0356 (CE3-related: On CCLM simplification) [F. Racapé (Technicolor)] [late]

[JVET-M0723](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5550) Crosscheck of JVET-M0356 (CE3-related: simplified calculation for CCLM parameters derivation) [G. Laroche, P. Onno (Canon)] [late]

[JVET-M0358](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5165) CE3-related: disabling PDPC based on availability of reference samples [V. Drugeon (Panasonic)]

[JVET-M0629](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5449) Crosscheck of JVET-M0358 (CE3-related: disabling PDPC based on availability of reference samples) [C. Rosewarne (Canon)] [late]

[JVET-M0365](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5172) Non-CE3: modified PDPC for horizontal and vertical modes [A. Filippov, V. Rufitskiy, J. Chen (Huawei)]

[JVET-M0804](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5635) Cross-check of contribution JVET-M0365 (Non-CE3: modified PDPC for horizontal and vertical modes) [M. Schäfer, J. Pfaff (HHI)] [late]

[JVET-M0383](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5190) Non-CE3: Table size reduction and bit width limitation for CCLM implementation [P. Onno, C. Gisquet, G. Laroche, J. Taquet (Canon)]

[JVET-M0741](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5572) Crosscheck of JVET-M0383 (Non-CE3: Table size reduction and bit width limitation for CCLM implementation) [A. Filippov, V. Rufitskiy (Huawei)] [late]

[JVET-M0384](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5191) Non-CE3: LM in the middle [C. Gisquet, G. Laroche, P. Onno, J. Taquet (Canon)]

[JVET-M0689](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5511) Crosscheck of JVET-M0384 (Non-CE3: LM in the middle) [J. Lainema (Nokia)] [late]

[JVET-M0391](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5199) CE3-related: Improvements on the Decoder-side Intra Mode Derivation [M. Abdoli, E. Mora, T. Guionnet, M. Raulet (ATEME)]

[JVET-M0651](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5472) Crosscheck of JVET-M0391 (CE3-related: Improvements on the Decoder-side Intra Mode Derivation) [F. Henry, G. Clare (Orange)] [late]

[JVET-M0392](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5197) Non-CE3: Extended Mode-Dependent Intra Smoothing [A. Filippov, V. Rufitskiy, J. Chen (Huawei)]

[JVET-M0803](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5634) Cross-check of contribution JVET-M0392 (Non-CE3: Extended Mode-Dependent Intra Smoothing) [M. Schäfer, J. Pfaff (HHI)] [late]

[JVET-M0426](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5235) CE3-related: Improvement on the Intra Sub-Partitions Coding Mode [S. De-Luxán-Hernández, V. George, J. Ma, T. Nguyen, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

[JVET-M0458](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5267) Non-CE3: Combined-Hypothesis Intra-Prediction [[G. Kulupana](mailto:gosala.kulupana@bbc.co.uk), [A. Seixas Dias](mailto:andre.seixasdias@bbc.co.uk), [S. Blasi (BBC)](mailto:saverio.blasi@bbc.co.uk)]

[JVET-M0613](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5433) Crosscheck of JVET-M0458 (Non-CE3: Combined-Hypothesis Intra-Prediction) [S. De-Luxán-Hernández (HHI)] [late]

[JVET-M0478](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5288) Non-CE3: PDPC extension [G. Van der Auwera, A. K. Ramasubramonian, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-M0682](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5504) Crosscheck of JVET-M0478 (Non-CE3: PDPC extension) [F. Racapé (Technicolor)] [late]

[JVET-M0493](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5303) CE3-related: Simplified look-up table for CCLM mode [L. Zhao, X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-M0624](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5444) Crosscheck of JVET-M0493 (CE3-related: Simplified look-up table for CCLM mode) [Y.-W. Chen (Kwai Inc.)] [late]

[JVET-M0494](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5304) CE3-related: Modifications on MPM list generation [L. Zhao, X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-M0745](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5576) Crosscheck of JVET-M0494 (CE3-related: Modifications on MPM list generation) [J. Luo (InterDigital)] [late]

[JVET-M0524](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5335) CE3/6-related: Unification of RQT-like transform partitioning for intra and inter blocks [H. Egilmez, V. Seregin, A. Said, M. Karczewicz (Qualcomm)]

[JVET-M0528](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5339) Non-CE3: A unified luma intra mode list construction process [F. Bossen, K. Misra (Sharp Labs of America)]

[JVET-M0626](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5446) Crosscheck of JVET-M0528 (Non-CE3: A unified luma intra mode list construction process) [J. Yao (Fujitsu)] [late]

[JVET-M0817](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5648) Crosscheck of JVET-M0528 (Non-CE3: A unified luma intra mode list construction process) [L. Zhao, X. Zhao (Tencent)] [late]

[JVET-M0653](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5473) Non-CE3: Harmonization of integer-slope directional modes without interpolation filtering process [A. Filippov, V. Rufitskiy, J. Chen (Huawei)] [late]

[JVET-M0802](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5633) Cross-check of contribution JVET-M0653 (Non-CE3: Harmonization of integer-slope directional modes without interpolation filtering process) [M. Schäfer, J. Pfaff (HHI)] [late]

[JVET-M0783](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5614) CE3-related: Modification of MPM list order [J. Heo, J. Choi, J. Choi, S. Yoo, L. Li, J. Lim, S. Kim (LGE)] [late]

[JVET-M0799](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5630) Bit-width reduction of multiplier in CCLM derivation and prediction [K. Kawamura, S. Naito (KDDI)] [late]

[JVET-M0844](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5675) Crosscheck of JVET-M0799 (Bit-width reduction of multiplier in CCLM derivation and prediction) [Y. Kato, K. Abe, T. Toma (Panasonic)] [late]

[JVET-M0815](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5646) CE3-related: Harmonization on MPM list [L. Li, J. Heo, J. Choi, S. Yoo, J. Choi, J. Lim, S. Kim (LGE)] [late]

[JVET-M0832](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5663) Non-CE3: On block size restrictions for PDPC with disabled linear filtering for PDPC in the case of skew non-diagonal modes [A. Filippov, V. Rufitskiy, J. Chen (Huawei), J. Lee, J. Kang (ETRI)] [late]

[JVET-M0866](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5697) Crosscheck of JVET-M0832 (Non-CE3: On block size restrictions for PDPC with disabled linear filtering for PDPC in the case of skew non-diagonal modes) [L Li (LGE)] [late]

## CE4 related – Inter prediction and motion vector coding (51)

Contributions in this category were discussed in BoG JVET-M0843 unless otherwise noted.

[JVET-M0067](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4869) Non-CE4: Weighted prediction with BDOF and bi-prediction with CU weights harmonization [T. Hashimoto, T. Chujoh, T. Ikai, E. Sasaki (Sharp)]

[JVET-M0394](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5201) Crosscheck of JVET-M0067 (Non-CE4: Weighted prediction with BDOF and bi-prediction with CU weights harmonization) [P. Bordes (Technicolor)] [late]

[JVET-M0068](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4870) Non-CE4: MMVD scaling fix [E. Sasaki, T. Ikai (Sharp)]

[JVET-M0509](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5320) Crosscheck of JVET-M0068 (Non-CE4: MMVD scaling fix) [X. Chen (HiSilicon)] [late]

[JVET-M0069](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4871) Non-CE4: Syntax change of MMVD [E. Sasaki, T. Chujoh, T. Ikai (Sharp)]

[JVET-M0554](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5367) Crosscheck of JVET-M0069 (Non-CE4: Syntax change of MMVD) [G. Li (Tencent)] [late]

[JVET-M0585](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5402) Crosscheck of JVET-M0069 (Non-CE4: Syntax change of MMVD) [K. Zhang (Bytedance)] [late]

[JVET-M0081](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4884) Non-CE4: Simplification of AMVP list generation in AMVR [Y. Kato, K. Abe, T. Toma (Panasonic)]

[JVET-M0807](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5638) Cross-check result of JVET-M0081 (Non-CE4: Simplification of AMVP list generation in AMVR) [K. Kawamura, S. Naito (KDDI)] [late]

[JVET-M0111](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4916) AHG13: On bi-prediction with weighted averaging and weighted prediction [Y. Ye, J. Chen, M. Yang (Alibaba), P. Bordes, E. François (Technicolor)]

[JVET-M0117](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4922) CE4-related: On MVP candidate list generation for AMVP [R. Yu, D. Liu, K. Andersson, P. Wennersten, J. Ström, R. Sjöberg (Ericsson)]

[JVET-M0763](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5594) Cross-check of JVET-M0117 [H. Jang, J. Nam, S.-H. Kim, J. Lim (LGE)] [late]

[JVET-M0127](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4932) CE4-related: Modification on Merge List [Y. Han, W.-J. Chien, D. Rusanovskyy, Y.-H. Chao, C.-C. Chen, H. Wang, H. Huang, C.-H. Hung, Y. Zhang, M. Karczewicz (Qualcomm)]

[JVET-M0532](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5344) Crosscheck of JVET-M0127 (CE4-related: Modification on Merge List) [H. Dou, Z. Deng, L. Xu (Intel)] [late]

[JVET-M0171](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4978) CE4-related: MMVD cleanups [C.-Y. Lai, T.-D. Chuang, Y.-L. Hsiao, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0757](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5588) Cross-check of JVET-M0171 (CE4-related: MMVD cleanups) [B.-J. Fuh, C.-H. Yau, C.-C. Lin (ITRI)] [late]

[JVET-M0193](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5000) CE4-related: Pairwise Average Candidate Reduction [A. Tamse, M. W. Park, K. Choi (Samsung)]

[JVET-M0551](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5364) Crosscheck of JVET-M0193 (CE4-related: Pairwise average candidate reduction) [S.-T. Hsiang (MediaTek)] [late]

[JVET-M0206](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5013) CE4-related: MMVD improvements [S. Jeong, M. W. Park, K. Choi (Samsung)]

[JVET-M0595](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5414) Crosscheck of JVET-M0206 (CE4-related: MMVD improvements) [T. Hashimoto, T. Ikai (Sharp)] [late]

[JVET-M0220](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5027) Non-CE4: Subjective quality analysis of non-sub-block ATMVP [Y.-H Chao, W.-J Chien, M. Karczewicz (Qualcomm)]

[JVET-M0230](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5037) CE4-related: Temporal MV buffer reduction [[Y.-W. Chen](mailto:yiwenchen@kwai.com), [X. Wang (Kwai Inc.)](mailto:xianglinwang@kwai.com)]

[JVET-M0591](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5410) Crosscheck of JVET-M0230 (Non-CE4: Temporal MV buffer reduction) [T. Zhou, T. Ikai (Sharp)] [late]

[JVET-M0231](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5038) CE4-related: Regular merge flag coding [X. Wang, Y.-W. Chen (Kwai Inc.)]

[JVET-M0559](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5372) Crosscheck of JVET-M0231 (Non-CE4: Regular merge flag coding) [H. Lee, S.-C. Lim, J. Lee, J. Kang (ETRI)] [late]

[JVET-M0845](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5676) Crosscheck of JVET-M0231 (Non-CE4: Regular merge flag coding) [T. Hashimoto, T. Ikai (Sharp)] [late]

[JVET-M0264](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5071) Non-CE4: Harmonization between HMVP and GBi [J. Li, S. Wang, W. Gao (Peking University), L. Zhang, K. Zhang, H. Liu, J. Xu (Bytedance), X. Xiu, D. Luo, Y. He (InterDigital)]

[JVET-M0574](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5388) Crosscheck of JVET-M0264 (Non-CE4: Harmonization between HMVP and GBi) [J. Zhao (LGE)] [late]

[JVET-M0267](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5074) Non-CE4: Harmonization of MMVD and AMVR [K. Zhang, L. Zhang, H. Liu, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-M0599](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5418) Crosscheck of JVET-M0267 (Non-CE4: Harmonization of MMVD and AMVR) [T. Hashimoto, T. Ikai (Sharp)] [late]

[JVET-M0272](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5079) CE4-related: Restrictions on History-based Motion Vector Prediction [L. Zhang, K. Zhang, H. Liu, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-M0642](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5462) Crosscheck of JVET-M0272 on CE4-related: Restrictions on History-based Motion Vector Prediction [X. Li (Tencent)] [late] [missing at end of meeting]

[JVET-M0286](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5093) Non-CE4: Simplifications for triangular prediction mode [T. Solovyev, S. Esenlik, S. Ikonin, J. Chen (Huawei)]

[JVET-M0793](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5624) Crosscheck of JVET-M0286 (Non-CE4: Simplifications for Triangular Prediction Mode) [C.-C. Chen, W.-J. Chien (Qualcomm)] [late]

[JVET-M0300](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5107) CE4-related: HMVP and parallel processing with tiles and tile groups [A. M. Kotra, J. Chen, B. Wang, S. Esenlik, H. Gao (Huawei)]

[JVET-M0307](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5114) CE4-related: Candidates optimization on MMVD [N. Park, H. Jang, J. Nam, J. Lim, S. Kim (LGE)]

[JVET-M0621](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5441) Crosscheck of JVET-M0307 (CE4-related: Candidates optimization on MMVD) [Y.-W. Chen (Kwai Inc.)] [late]

[JVET-M0779](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5610) Crosscheck of JVET-M0307 (CE4-related: Candidates optimization on MMVD) [T. Hashimoto, T. Ikai (Sharp)] [late]

[JVET-M0308](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5115) Non-CE4: MMVD simplification [X. Chen, J. Zheng (HiSilicon)]

[JVET-M0592](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5411) Crosscheck of JVET-M0308 (Non-CE4: MMVD simplification) [T. Hashimoto, T. Ikai (Sharp)] [late]

[JVET-M0314](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5121) CE4-related: MMVD improving with signaling distance table [J. Li, R.-L. Liao, C. S. Lim (Panasonic)]

[JVET-M0597](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5416) Crosscheck of JVET-M0314 (CE4-related: MMVD improving with signaling distance table) [T. Hashimoto, T. Ikai (Sharp)] [late]

[JVET-M0315](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5122) Non-CE4: MMVD scaling simplification [J. Li, R.-L. Liao, C. S. Lim (Panasonic)]

[JVET-M0794](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5625) Crosscheck of JVET-M0315 (Non-CE4: MMVD Scaling Simplification) [C.-C. Chen, W.-J. Chien (Qualcomm)] [late]

[JVET-M0330](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5137) CE4-related: Simplification of MMVD scheme [L. Xu, F. Chen, L. Wang (Hikvision)]

[JVET-M0590](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5409) Crosscheck of JVET-M0330 (CE4-related: Simplification of candidate list derivation for MMVD mode) [T. Hashimoto, T. Ikai (Sharp)] [late]

[JVET-M0345](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5152) CE4-related: Remove redundancy between TMVP and ATMVP [S. H. Wang (Peking University), X. Zheng (DJI), S.S. Wang, S.W. Ma (Peking University)]

[JVET-M0754](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5585) Cross-check of JVET-M0345: CE4-related: Remove redundancy between TMVP and ATMVP [S. Bandyopadhyay (InterDigital)] [late]

[JVET-M0346](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5153) CE4-related: Non-square compression grid for temporal motion data storage [S. H. Wang (Peking University), X. Zheng (DJI), S.S. Wang, S.W. Ma (Peking University)]

[JVET-M0348](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5155) CE4-related: Improvement on 4x4 bi-prediction [X. W. Meng (Peking University), X. Zheng (DJI), S.S. Wang, S.W. Ma (Peking University)]

[JVET-M0809](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5640) Crosscheck of JVET-M0348: CE4-related: Further reducing VVC memory bandwidth worst case by combining 4x4/4x8/8x4 bi-prediction with AMVR [L. Pham Van, W.-J. Chien, M. Karczewicz (Qualcomm)] [late]

[JVET-M0350](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5157) CE4-related: Quadtree-based Merge Estimation Region for VVC [T. L. Fu (Peking University), X. Zheng (DJI), S.S Wang, S.W. Ma (Peking University)]

[JVET-M0583](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5400) Crosscheck of JVET-M0350 (CE4-related: Quadtree-based Merge Estimation Region for VVC) [G. Li (Tencent)] [late]

[JVET-M0359](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5166) Non-CE4: Modification of merge data syntax [G. Ko, D. Kim, J. Jung, J. Son, J. Kwak (WILUS)]

[JVET-M0789](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5620) Crosscheck of JVET-M0359 (Non-CE4: Modification of merge data syntax) [B. Lee (Chosun Univ.)] [late]

[JVET-M0369](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5176) CE4-related: Syntax changes of merge data [Y. Ahn, D. Sim (Digital Insights)] [late]

[JVET-M0750](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5581) Cross-check of JVET-M0369 (CE4-related: Syntax changes of merge data) [S.-C. Lim, H. Lee, J. Lee, J. Kang (ETRI)] [late]

[JVET-M0405](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5213) CE4-related: Simplified merge candidate list for small blocks [X. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0659](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5480) Crosscheck of JVET-M0405 (CE4-related: Simplified merge candidate list for small blocks) [K. Choi (Samsung)] [late]

[JVET-M0406](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5214) CE2/4-related: Unified merge list size for block and sub-block merge modes [X. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0422](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5231) CE4-related: Simplified MVD coding [X. Li, X. Xu, X. Zhao, S. Liu (Tencent)]

[JVET-M0440](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5249) Crosscheck of JVET-M0422 (CE4-related: Simplified MVD coding) [L. Zhang (Bytedance)] [late]

[JVET-M0433](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5242) CE4-related: Constraint on GBi index inheritance in Merge Mode [G. Li, X. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0700](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5522) Cross-check of JVET-M0433 (CE4-related: Constraint on GBi index inheritance in Merge Mode [J. Zhao (LGE)]

[JVET-M0435](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5244) CE4-related: MMVD offset table signaling [G. Li, X. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0623](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5443) Crosscheck of JVET-M0435 (CE4-related: MMVD offset table signaling) [Y.-W. Chen (Kwai Inc.)] [late]

[JVET-M0436](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5245) AHG2: Regarding HMVP Table Size [J. Zhao, S. Kim (LGE)]

[JVET-M0562](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5375) Cross-check of JVET-M0436: AHG2: Regarding HMVP Table Size [S. Bandyopadhyay (InterDigital)] [late]

[JVET-M0437](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5246) Non-CE4: Size constraint on MMVD [J. Zhao, S. Kim (LGE)]

[JVET-M0555](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5368) Crosscheck of JVET-M0437 (Non-CE4: Size constraint on MMVD) [G. Li (Tencent)] [late]

[JVET-M0444](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5253) CE4-related: Simplified symmetric MVD based on CE4.4.3 [J. Luo, Y. He (InterDigital)]

[JVET-M0721](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5548) Crosscheck of JVET-M0444 (CE4-related: Simplified symmetric MVD based on CE4.4.3) [H. Chen, T. Solovyev (Huawei)] [late]

[JVET-M0448](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5257) CE4-related: Triangle merge index signaling [M. Xu, X. Li, S. Liu (Tencent)]

[JVET-M0836](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5667) Crosscheck of JVET-M0448 (CE4-related: Triangle merge index signaling) [X. Wang (Kwai Inc.)] [late]

[JVET-M0473](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5283) Simplified HMVP [W. Zhu, A. Segall (Sharp)]

[JVET-M0778](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5609) Crosscheck of JVET-M0473: Simplified HMVP [C.-H. Hung, W.-J. Chien (Qualcomm)] [late]

[JVET-M0479](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5289) Non-CE4: On clipping of scaled motion vectors [K. Misra, F. Bossen (Sharp)]

[JVET-M0777](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5608) Crosscheck of JVET-M0479: Non-CE4: On clipping of scaled motion vectors [[C.-H. Hung](mailto:chaohsiu@qti.qualcomm.com), [W.-J. Chien (Qualcomm)](mailto:wchien@qti.qualcomm.com)] [late]

[JVET-M0484](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5294) Non-CE4: Line buffer size reduction method for generalized bi prediction [T. Solovyev, H. Gao, S. Esenlik, S. Ikonin, J. Chen (Huawei)]

[JVET-M0819](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5650) Crosscheck of JVET-M0484 (Non-CE4: Line buffer size reduction method for generalized bi prediction) [A. Robert (Technicolor)] [late]

[JVET-M0519](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5330) Non-CE: Context modeling for coding the prediction mode flag [S.-T. Hsiang, S.-M. Lei (MediaTek)]

[JVET-M0739](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5570) Crosscheck of JVET-M0519 (Non-CE: Context modeling for coding the prediction mode flag) [A. Tamse (Samsung)] [late]

[JVET-M0502](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5312) CE4-related: Improved context for prediction mode flag [X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-M0657](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5478) Crosscheck of JVET-M0502 (CE4-related: Improved context for prediction mode flag) [K. Choi (Samsung)] [late]

[JVET-M0513](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5324) CE7-related: Context modeling of pred\_mode\_flag [Y. Zhao, S. Hong, H. Yang, J. Chen (Huawei)]

[JVET-M0882](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5713) Cross check of CE7-related: Context modeling of pred\_mode\_flag (JVET-M0513) [M. W. Park, H. Yang (Samsung)] [late]

[JVET-M0507](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5318) CE4-related: Hybrid Merge Estimation Region [H. Wang, V. Seregin, W.-J. Chien, T. Hsieh, Y. Han, M. Karczewicz (Qualcomm)]

[JVET-M0712](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5535) Crosscheck of JVET-M0507 (CE4-related: Hybrid Merge Estimation Region) [F. Chen, L. Wang (Hikvision)] [late]

[JVET-M0837](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5668) Crosscheck of JVET-M0507 (CE4-related: Hybrid Merge Estimation Region) [X. Wang (Kwai Inc.)] [late]

[JVET-M0512](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5323) Non-CE4: On Temporal Motion Buffer Compression [F. Bossen, K. Misra, A. Segall (Sharp Labs of America)]

[JVET-M0764](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5595) Cross-check of JVET-M0512 [H. Jang, J. Nam, S.-H. Kim, J. Lim (LGE)] [late]

[JVET-M0518](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5329) CE4-related: Supplemental results on STMVP design of CE4.2.3.a and combination with methods of JVET-M0127 (CE4.1.2.a) and JVET-M0127 [D. Rusanovskyy, Y.-H. Chao, Y. Han, W.-J. Chien, M. Karczewicz (Qualcomm)]

[JVET-M0820](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5651) Crosscheck of JVET- M0518 (CE4-related: Supplemental results on STMVP design of CE4.2.3.a and combination with methods of JVET-M0127 (CE4.1.2.a) and JVET-M0127) [T. Y. Zhou, T. Ikai (Sharp)] [late]

[JVET-M0625](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5445) Crosscheck of JVET-M0518 (CE4-related: Supplemental results on STMVP design of CE4.2.3.a and combination with methods of JVET-M0127 (CE4.1.2.a) and JVET-M0127) [Y.-W. Chen (Kwai Inc.)] [late]

[JVET-M0627](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5447) Non-CE4: Supplementary results of combined solution of JVET-M0255, JVET-M0267 and JVET-M0069 [H. Liu, K. Zhang, L. Zhang (Bytedance), E. Sasaki, T. Chujoh, T. Ikai (Sharp)] [late]

[JVET-M0895](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5726) Cross-check result of JVET-M0627 (Non-CE4: Supplementary results of combined solution of JVET-M0255, JVET-M0267 and JVET-M0069) [K. Kawamura, S. Naito (KDDI)] [late]

[JVET-M0661](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5482) AhG-13: On Merge List Size [X. Li, X. Xu, S. Liu (Tencent)] [late]

[JVET-M0713](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5536) CE4-related: simplification of CE4.2.2 [F. Le Léannec, A. Robert, T. Poirier (Technicolor)] [late]

[JVET-M0786](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5617) Crosscheck of JVET-M0713 (CE4-related: simplification of CE4.2.2) [Y.-H. Chao (Qualcomm)] [late]

[JVET-M0823](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5654) CE4-related: Encoder optimization of CE4.4.5 [J. Li, R.-L. Liao, C. S. Lim (Panasonic)] [late]

This contribution provides the simulation results of encoder optimization algorithm used in JVET-M0312 CE4: MMVD improvement (test 4.4.5). Experimental results show 0.11% (RA) and 0.08% (LDB) luma BD-rate reduction with 3-5% increase in encoding timing time and no impact on decoding time.

Reviewed in Track B Thu 17 Jan 1600 (JRO), as this seemed to be the current best known encoder for MMVD.

Decision (SW): Adopt JVET-M0823, and also use in CTC.

[JVET-M0833](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5664) Crosscheck of JVET-M0823 (CE4-related: Encoder optimization of CE4.4.5) [C.-C. Chen, W.-J. Chien (Qualcomm)] [late]

[JVET-M0854](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5685) CE4-related: Combination of CE4.4.4a and CE4.4.5b [T. Hashimoto, E. Sasaki, T. Ikai (Sharp), J. Li, R.-L. Liao, C. S. Lim (Panasonic)] [late]

This contribution reports results of combining CE4.4.4.a and CE4.4.5.b. It shows 0.2% B-D rate reduction with 100% encoding time and 100% decoding time in RA condition and 0% B-D rate reduction with 100% encoding time and 100% decoding time in LDB condition, compared to a VTM3+4.4.5\* anchor.

Reviewed in Track B Thu 17 Jan 1600.

The aspect of 4.4.5.b was already resolved by adoption of M0255 (via explicit signalling). Aspect of 4.4.4a should be investigated in ongoing CE.

[JVET-M0861](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5692) Crosscheck of JVET-M0854: (CE4-related: Combination of CE4.4.4a and CE4.4.5b) [V. Seregin (Qualcomm)] [late]

## CE5 related – Arithmetic coding engine (5)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

[JVET-M0089](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4892) Non-CE5: CABAC skip mode for super low delay [K. Abe, T. Toma (Panasonic)]

Presented Thu 7:40pm. Chaired by FJB

Because CABAC requires sequential processing, the number of processing cycles of CABAC may fluctuate due to the change in the local bit amount. Some systems introduce a kind of buffering to avoid it, but it would be a cause of delay especially for the use case of high bitrate with low performance hardware. This contribution proposes to introduce CABAC skip mode which directly outputs binarized bits as a bitstream without CABAC processing. This mode decreases the coding efficiency, but it is very useful for the super low delay use cases which need to guarantee several milliseconds delay. Simulation results reportedly show that the proposed mode can guarantee the fixed delay with the cost of 23%, 25%, and 30% bits increasing for AI, RA, and LDB on VTM-3.0.

Question about HRD assumptions. It was mentioned that there may not be a problem to be solved here.

This could be further discussed in AHG16 ( implementation complexity ) or AHG14 (progressive intra refresh).

No action at this time.

[JVET-M0344](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5151) Crosscheck of JVET-M0089 (Non-CE5: CABAC skip mode for super low delay) [R. Hashimoto (Renesas)]

[JVET-M0196](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5003) CE5-related: Counter-based multi-CABAC for partial context models [Y. Piao, K. Choi (Samsung)]

Detailed presentation of this was not requested by the presenter, due to actions taken earlier at the meeting.

[JVET-M0545](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5358) Crosscheck of JVET-M0196 (CE5-related: Counter-based multi-CABAC for partial context models) [J. Dong (Qualcomm)] [late]

[JVET-M0389](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5196) CE5-related: Minor optimizations for increasing the throughput of CE5.1.5 and CE5.1.6 [H. Kirchhoffer, C. Bartnik, P. Haase, T. Hinz, S. Matlage, B. Stabernack, J. Stegemann, D. Marpe, H. Schwarz, T. Wiegand (HHI)]

Detailed presentation of this was not requested by the presenter, due to actions taken earlier at the meeting.

[JVET-M0395](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5202) CE5-related: Alternative implementation of CABAC range sub-interval derivation for CE5.1.5, CE5.1.6 and CE5.1.7 [P. Haase, H. Kirchhoffer, S. Matlage, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

Detailed presentation of this was not requested by the presenter, due to actions taken earlier at the meeting.

[JVET-M0772](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5603) CE5-related: Clean up of the context model initialization process for CE5.1.5 and CE5.1.6 [J. Stegemann, H. Kirchhoffer, D. Marpe, H. Schwarz, T. Wiegand (HHI)] [late]

Detailed presentation of this was not requested by the presenter, due to actions taken earlier at the meeting.

## CE6 related – Transforms and transform signalling (25)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

Contribution JVET-M0538 had been discussed in the CE report but was not part of the CE. See the CE report for some discussion of this.

[JVET-M0046](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4848) CE6-related: A study of primary transforms [M. Zhou, Y. Hu (Broadcom)]

[JVET-M0465](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5274) Cross-check of JVET-M0046: CE6-related: A study of primary transforms [S. Bandyopadhyay (InterDigital)]

[JVET-M0072](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4874) Non-CE6: On transform skip for larger block [T. Tsukuba, M. Ikeda, T. Suzuki (Sony)]

[JVET-M0748](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5579) Crosscheck of JVET-M0072, in aspect of 8x8 transform skip extension (Non-CE6: On transform skip for lager block) [S. Yoo, J.Lim (LGE)] [late]

[JVET-M0637](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5457) Crosscheck of JVET-M0072 (Non-CE6: On transform skip for lager block) [[T. Toma](mailto:toma.tadamasa@jp.panasonic.com), K. Abe (Panasonic)] [late]

[JVET-M0085](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4888) CE6-related: Fast algorithm for DST-4/DCT-4 as alternative transforms for MTS [T. Toma, K. Abe (Panasonic), M. Ikeda, T. Tsukuba (Sony)]

[JVET-M0800](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5631) Cross-check report of JVET-M0085 on Fast algorithm for DST-4/DCT-4 as alternative transforms for MTS (CE6-related) [K. Naser (Technicolor)] [late]

[JVET-M0201](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5008) CE6-related: Syntax clean-up related to MTS [K. Choi, M. Park, M. W. Park, W. Choi (Samsung)]

[JVET-M0671](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5492) Crosscheck of JVET-M0201 (CE6-related: Syntax clean-up related to MTS) [X. Cao (Hikvision)] [late]

[JVET-M0202](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5009) CE6-related: Simplification related to MTS with reduced modes [K. Choi, M. Park, M. W. Park, W. Choi (Samsung)]

[JVET-M0672](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5493) Crosscheck of JVET-M0202 (CE6-related: Simplification related to MTS with reduced modes) [X. Cao (Hikvision)] [late]

[JVET-M0269](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5076) Non-CE6: Extension of transform skip block size to 8x8 [S. Yoo, J. Choi, J. Heo, J. Choi, L. Li, J. Lim, S. Kim (LGE)]

[JVET-M0709](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5532) Crosscheck of JVET-M0269 (Non-CE6: Extension of transform skip block size to 8x8) [T. Tsukuba (Sony)] [late]

[JVET-M0275](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5082) Non-CE6: On transform skip conditions [S. Yoo, J. Choi, J. Heo, J. Choi, L. Li, J. Lim, S. Kim (LGE)]

[JVET-M0846](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5677) Cross-check of JVET-M0275 (Non-CE6: On transform skip conditions) [P. Keydel (HHI)] [late]

[JVET-M0280](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5087) CE6-related: Context selection for entropy coding the MTS flag [S.-T. Hsiang, S.-M. Lei (MediaTek)]

[JVET-M0738](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5569) Crosscheck of JVET-M0280 (CE6-related: Context selection for entropy coding the MTS flag) [A. Tamse (Samsung)] [late]

[JVET-M0297](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5104) CE6-related: 32 point MTS based on skipping high frequency coefficients [M. Koo, M. Salehifar, J. Lim, S. Kim (LGE)]

[JVET-M0801](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5632) Cross-check report of JVET-M0297 on 32 point MTS based on skipping high frequency coefficients (CE6-related) [K. Naser (Technicolor)] [late]

[JVET-M0304](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5111) CE6-related: 2-mode MTS with shape adaptive transform selection [J. Lainema (Nokia)]

[JVET-M0340](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5147) CE6-related: Simplification on MTS for intra residual coding [X. Cao, F. Chen, L.Wang (Hikvision)]

[JVET-M0654](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5475) Crosscheck of JVET-M0340 (CE6-related: Simplification on MTS for intra residual coding) [K. Choi (Samsung)] [late]

[JVET-M0347](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5154) CE6-related: On MTS CU flag coding [X. Cao, F. Chen, L. Wang (Hikvision)]

[JVET-M0655](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5476) Crosscheck of JVET-M0347 (CE6-related: Simplification on MTS CU flag coding) [K. Choi (Samsung)] [late]

[JVET-M0354](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5161) CE6-related: MTS with Haar transform for Screen Contents Coding [K. Naser, F. Galpin, T. Poirier (Technicolor)]

[JVET-M0869](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5700) Cross-check report of JVET-M0354 (CE6-related: MTS with Haar transform for Screen Contents Coding) [M. Koo (LGE)] [late]

[JVET-M0361](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5168) Non-CE6: Mismatch between text specification and reference software on the signalling root CBF [J. Jung, D. Kim, G. Ko, J. Son, J. Kwak (WILUS)]

[JVET-M0790](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5621) Cross-check of JVET-M0361 (Non-CE6: Mismatch between text specification and reference software on the signalling root CBF) [B. Lee (Chosun Univ.)] [late]

[JVET-M0366](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5173) CE6 related: Transform Simplification [C. Hollman, D. Saffar, P. Wennersten, J. Ström (Ericsson)]

[JVET-M0876](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5707) Crosscheck for JVET-M0366 (CE-6 related: Transform Simplification) [J. Rasch (HHI)] [late]

[JVET-M0379](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5186) CE6-related: Further Simplification on top of CE6-2.2 [K. Naser, E. François, F. Le Léannec (Technicolor)]

[JVET-M0638](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5458) Crosscheck of JVET-M0379 (CE6-related: Further Simplification on top of tests CE6-2.2) [T. Toma, K. Abe (Panasonic)] [late]

[JVET-M0396](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5203) CE6-related: MTS kernel derivation for efficient memory usage [S. Shrestha, A. Kumar, B. Lee (Chosun Univ), Y. Lee, J. Park (Humax)] [late]

Initial upload rejected as a placeholder.

[JVET-M0773](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5604) Crosscheck of JVET-M0396 (“CE6-related: MTS kernel derivation for efficient memory usage”) [J. Jung, D. Kim, G. Ko, J. Son, J. Kwak (WILUS)] [late]

[JVET-M0397](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5204) CE6-related: DST-3 based transform kernels derivation [S. Shrestha, A. Kumar, B. Lee (Chosun Univ.), Y. Lee, J. Park (Humax)]

[JVET-M0852](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5683) Crosscheck of JVET-M0397 (CE6-related: DST-3 based transform kernels derivation) [J. Kim, K. Ko, J. Jung] [late]

[JVET-M0398](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5205) CE6-related Further simplification of CE6-1.5 [P. Philippe (bcom Orange)]

[JVET-M0480](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5290) CE6-related: Implicit transform selection for Multi directional LM [S. Iwamura, S. Nemoto, A. Ichigaya (NHK)]

[JVET-M0573](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5387) Crosscheck of JVET-M0480 (CE6-related: Implicit transform selection for Multi directional LM) [K. Kazui (Fujitsu)] [late]

[JVET-M0482](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5292) CE6-related: Implicit transform selection for Multi-hypothesis inter-intra mode [S. Iwamura, S. Nemoto, A. Ichigaya (NHK)]

[JVET-M0569](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5382) Crosscheck of JVET-M0482 (CE6-related: Implicit transform selection for Multi-hypothesis inter-intra mode) [T. Chujoh (Sharp)] [late]

[JVET-M0501](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5311) CE6 related: Unification of Transform Skip mode and MTS [X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-M0656](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5477) Crosscheck of JVET-M0501 (CE6 related: Unification of Transform Skip mode and MTS) [K. Choi (Samsung)] [late]

[JVET-M0524](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5335) CE3/6-related: Unification of RQT-like transform partitioning for intra and inter blocks [H. Egilmez, V. Seregin, A. Said, M. Karczewicz (Qualcomm)]

[JVET-M0847](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5678) Cross-check of JVET-M0524 (CE3/6-related: Unification of RQT-like transform partitioning for intra and inter blocks) [P. Philippe (bcom Orange)] [late]

[JVET-M0538](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5350) CE6: Efficient Implementations of MTS with Transform Adjustments (tests 1.4a-d) [A. Said, H.E. Egilmez, Y.-H. Chao, V. Seregin, M. Karczewicz (Qualcomm)] [late]

This had been included in the CE report but was a late contribution that was not in the CE plan.

[JVET-M0539](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5351) CE6-related: Efficient computation of MTS transform combinations [A. Said, H.E. Egilmez, Y.-H. Chao, V. Seregin, M. Karczewicz (Qualcomm)] [late]

[JVET-M0540](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5352) CE6-related: Software tool for computing transform throughput [A. Said, H.E. Egilmez, Y.H. Chao, V. Seregin, M. Karczewicz (Qualcomm)] [late]

## CE7 related – Quantization and coefficient coding (17)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

[JVET-M0107](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4912) CE7-related: reduced local neighbourhood usage for transform coefficients coding [F. Le Léannec, Y. Chen (Technicolor)]

[JVET-M0781](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5612) Cross-Check of JVET-M0107 (CE7-related: reduced local neighborhood usage for transform coefficients coding) [M. Gao (Tencent)] [late]

[JVET-M0198](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5005) CE7-related: Unified Rice parameter derivation for coefficient level coding [Y. Piao, K. Choi (Samsung)]

[JVET-M0668](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5489) Crosscheck of JVET-M0198 (CE7-related: Unified Rice parameter derivation for coefficient level coding) [M. Coban (Qualcomm)] [late]

[JVET-M0250](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5057) Non-CE7: Simplified CSBF coding for large block-size transforms [J. Choi, J. Heo, S. Yoo, J. Choi, L. Li, J. Lim, S. Kim (LGE)]

[JVET-M0760](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5591) Crosscheck of JVET-M0250 (Non-CE7: Simplified CSBF coding for large block-size transforms) [Z.-Y. Lin (MediaTek)] [late]

[JVET-M0251](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5058) Non-CE7: Last position coding for large block-size transforms [J. Choi, J. Heo, S. Yoo, J. Choi, L. Li, J. Lim, S. Kim (LGE)]

[JVET-M0646](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5467) Crosscheck of JVET-M0251 (Non-CE7: Last position coding for large block-size transforms) [H. Schwarz (Fraunhofer HHI)] [late]

[JVET-M0257](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5064) CE7-related: Coefficient scanning and last position coding for TUs of greater than 32 width or height [M. Coban, M. Karczewicz (Qualcomm)]

[JVET-M0761](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5592) Crosscheck of JVET-M0257 (CE7-related: Coefficient scanning and last position coding for TUs of greater than 32 width or height) [Z.-Y. Lin (MediaTek)] [late]

[JVET-M0278](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5085) Non-CE7: Residual rearrangement for transform skipped blocks [S. Yoo, J. Choi, J. Heo, J. Choi, L. Li, J. Lim, S. Kim (LGE)]

[JVET-M0683](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5505) Crosscheck of JVET-M0278 (Non-CE7: Residual rearrangement for transform skipped blocks) [Y.-C. Lin (MediaTek)] [late]

[JVET-M0279](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5086) Non-CE7: Sign coding for transform skip [S. Yoo, J. Choi, J. Heo, J. Choi, L. Li, J. Lim, S. Kim (LGE)]

[JVET-M0649](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5470) Crosscheck of JVET-M0279 (Non-CE7: Sign coding for transform skip) [F. Henry, G. Clare (Orange)] [late]

[JVET-M0305](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5112) CE7-related: Joint coding of chrominance residuals [J. Lainema (Nokia)]

[JVET-M0688](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5510) Cross-check of JVET-M0305, "CE7-related: Joint coding of chrominance residuals" [C. Gisquet (Canon)] [late]

[JVET-M0469](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5279) CE7-related: Unified Rice parameter derivation for coefficient coding [M. Karczewicz, M. Coban (Qualcomm)]

[JVET-M0647](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5468) Crosscheck of JVET-M0469 (CE7-related: Unified Rice parameter derivation for coefficient coding) [H. Schwarz (Fraunhofer HHI)] [late]

[JVET-M0470](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5280) CE7-related: Golomb-Rice/exponential Golomb coding for abs\_remainder and dec\_abs\_level syntax elements [M. Coban, M. Karczewicz (Qualcomm)]

[JVET-M0831](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5662) Cross-check of JVET-M0470 (CE7-related: Golomb-Rice/exponential Golomb coding for abs\_remainder and dec\_abs\_level syntax elements) [K. Sharman, S. Keating (Sony)] [late]

[JVET-M0489](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5299) CE7-related: Reduced context models for transform coefficients coding [M. Gao, X. Li, X. Zhao, S. Liu (Tencent)]

[JVET-M0697](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5519) Cross-check of JVET-M0489 "CE7-related: Reduced context models for transform coefficients coding" [Y. Chen, F. Le Léannec (Technicolor)] [late]

[JVET-M0491](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5301) CE7-related: Reduced the maximum number of context-coded bins for transform coefficient coding [M. Gao, X. Li, X. Zhao, S. Liu (Tencent)]

[JVET-M0684](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5506) Crosscheck of JVET-M0491 (CE7-related: Reduced the maximum number of context-coded bins for transform coefficient coding) [Y.-C. Lin (MediaTek)] [late]

[JVET-M0558](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5371) CE7-related: Template based Rice parameter derivation [M. Karczewicz (Qualcomm)] [late]

[JVET-M0660](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5481) Crosscheck of JVET-M0558 [Y. Piao, K. Choi (Samsung)] [late]

## CE8 related – Screen content coding tools (29)

Contributions in this category were discussed Friday 11 Jan. 1620–2010 and Saturday 1815-2130 (Track B chaired by JRO).

See also M0418 on context modeling for CPR.

[JVET-M0151](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4958) CE8-related: Virtual search area for current picture referencing (CPR) [L. Pham Van, T. Hsieh, W.-J. Chien, V. Seregin, H. Wang, M. Karczewicz (Qualcomm)]

This contribution proposes a method to extend the CPR search area by padding the area using the line buffer and the column to the left of the current CTU. Without any additional memory cost, the luma BD-rate changes for [CTC, Class F, class SCC 1080p] with the use of the proposed technique are reported as test 1:

*CPR on and PLT off:*

*AI: (0.02%, -0.39%, -1.23%) over VTM3+CPR on, resp.*

*RA: (0.02%, -0.29%, -0.60%) over VTM3+CPR on, resp.*

*LB: (-0.03%, -0.20%, -0.35%) over VTM3+CPR on, resp.*

*CPR on and PLT on:*

*AI: (0.03%, -0.09%, -0.31%) over VTM3+CPR+PLT on, resp.*

*RA:( 0.03%, -0.12%, -0.35%) over VTM3+CPR+PLT on, resp.*

*LB:( 0.01%, -0.27%, -0.17%) over VTM3+CPR+PLT on, resp.*

Test 2: In addition, this document also reports the results of the proposed padding scheme when 4 lines above and 4 columns to the left of the current CTU are included into the CPR search area.

Test 2 is not realistic, as only one line buffer is available

Test 1 is kind of extension of CE 8.1.3, which uses only 1 line without padding

It is pointed out by one expert that a similar method of padding could also be used generally when an MV in CPR would point outside the valid range

Padding generally is not of much complexity concern

Further study.

[JVET-M0174](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4981) CE8-related: Removal of subblock-based chroma MC in CPR [C.-Y. Lai, T.-D. Chuang, Y.-L. Hsiao, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

This contribution proposes a modification on current picture referencing (CPR). In the current CPR, when dual tree coding is enabled, a chroma coding unit (CU) selecting CPR inter mode has to check all collocated luma subblock motion vectors (MVs), scale the collocated luma subblock MVs for chroma, and perform subblock-based chroma motion compensation (MC) if all the collocated luma subblock MVs are available and valid. To simplify the chroma CPR inter CUs in dual tree coding, it is proposed to use only the center collocated luma subblock MV to replace subblock-based chroma MC with CU-based chroma MC. Two default MVs can be checked when the center collocated luma subblock MV is unavailable or invalid. Simulation results are as follows, where the anchor enabled CPR.

For common test condition (CTC) sequences without class F  
VTM3.0-AI: {Y/U/V-BD-rate = 0.00% / -0.04% / -0.06%, EncT=100%, DecT=99%}  
VTM3.0-RA: {Y/U/V-BD-rate = 0.01%/ -0.07% / -0.04%, EncT=100%, DecT=99%}

For class F sequences  
VTM3.0-AI: {Y/U/V-BD-rate = -0.04% / -0.25% / -0.14%, EncT=101%, DecT=100%}  
VTM3.0-RA: {Y/U/V-BD-rate = -0.04% / -0.21% / -0.07%, EncT=100%, DecT=101%}

For TGM sequences  
VTM3.0-AI: {Y/U/V-BD-rate = -0.27% / -0.47% / -0.55%, EncT=101%, DecT=101%}  
VTM3.0-RA: {Y/U/V-BD-rate = -0.06% / -0.25% / -0.25%, EncT=100%, DecT=99%}

It is pointed out that one of the design goals of keeping luma and chroma aligned in CPR with dual tree was to avoid luma/chroma mismatches (which might be critical in screen content with sharp edges).Not clear if this would be critical in terms of complexity; compression gain is not an argument; more evidence would be necessary that the current design is overly complicated and would need additional checks at the encoder to guarantee the compliance of a vector. The decoder complexity is not a big issue as long as the decoder can trust an encoder to deliver a valid vector.

[JVET-M0769](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5600) Crosscheck of JVET-M0174 (CE8-related: Removal of subblock-based chroma MC in CPR) [T.-S. Chang, Y.-C. Sun, J. Lou (Alibaba)] [late]

[JVET-M0175](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4982) CE8-related: Clarification on interaction between CPR and other inter coding tools [C.-Y. Lai, T.-D. Chuang, Y.-L. Hsiao, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

In VTM3.0 encoder, current picture referencing (CPR) for each coding unit (CU) is never tested with combined inter intra prediction (CIIP), merge mode with motion vector difference (MMVD), and subblock modes including subblock-based temporal motion vector prediction (SbTMVP) merge mode, affine merge mode, and affine inter mode. When the reference picture list contains only the current picture and no other reference picture, mh\_intra\_flag (indicating CIIP on/off of the CU; it is suggested to rename it as ciip\_flag), mmvd\_flag (indicating MMVD on/off of the CU), merge\_subblock\_flag (equal to 1 indicating SbTMVP merge or affine merge is on; equal to 0 indicating SbTMVP merge and affine merge are off), and inter\_affine\_flag (indicating affine inter mode on/off) are always zero and still signalled. In addition, in both VTM3.0 decoder and VVC draft text JVET-L1001-v7.docx, decoding process is not defined. This contribution proposes two methods to deal with this issue. Method 1 is to add a normative encoder-only constraint in the VVC draft text, i.e., conformant encoders shall not enable any of the four flags when CPR is enabled at CU level. Method 2 is to skip signalling and parsing the above four flags when the reference picture list only contains the current picture at encoder and decoder, respectively. Method 1 does not cause any BD-rate change for VTM3.0. Method 2 reportedly causes minor BD-rate impact. It is claimed that Method 2 is a preferred solution than Method 1 in order to reduce the possibility of related illegal bitstreams generated by careless encoders.

Method1 was already included in V8 of VVC draft 3, therefore the problem is solved. The addititional benefit of method 2 is minimum (if at all present, as it might require additional low-level checks of decoder).

[JVET-M0770](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5601) Crosscheck of JVET-M0175 (CE8-related: Clarification on interaction between CPR and other inter coding tools) [T.-S. Chang, Y.-C. Sun, J. Lou (Alibaba)] [late] [missing at end of meeting]

[JVET-M0253](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5060) Non-CE8: Hash-based Motion Search [J. Xu, J. Li, K. Zhang, L. Zhang (Bytedance), R. Xiong (Peking University)]

This contribution presents a hash-based motion search scheme for the VVC test model. For 4x4 to 64x64 square blocks and 4x8, 8x4 blocks, a hash table is generated for each reference picture. A hash-based block matching is then performed before existing motion estimation for those block sizes. When a block finds its match, the following motion estimation can be skipped. For TGM sequences, experimental results report 9.6% and 18.87% coding gain for RA and LD\_B, with encoding time reduced to 89% and 88%. When CPR is on, 7.81% and 14.91% coding gain is reported, with encoding time reduced to 91% and 89%.

Basically, same apporach as known from HEVC-SCC

The new algorithm automatically detects if hash-based search is applicable and switches to conventional search. This does not increase encoder run time (according to tables III and IV of v2 of the doc).

Decision (SW): Adopt JVET-M0253.

[JVET-M0704](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5527) Crosscheck for JVET-M0253: Non-CE8: Hash-based Motion Search [X. Xu (Tencent)] [late]

[JVET-M0254](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5061) Non-CE8: Subblock Operation Removal for Chroma CPR [J. Xu, K. Zhang, L. Zhang, H. Liu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

In the current design of CPR, when separate tree is applied, chroma blocks inherit collocated luma blocks’ block vectors, which requires sub-block by sub-block operation. This contribution proposes to remove such a subblock-wise operation and reports a 0.26% coding gain for class TGM420.

Similar to JVET-M0174 (see notes on that contribution).

[JVET-M0785](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5616) Crosscheck of JVET-M0254 (Non-CE8: Subblock Operation Removal for Chroma CPR) [Y.-H. Chao (Qualcomm)] [late]

[JVET-M0255](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5062) AHG11: MMVD without Fractional Distances for SCC [H. Liu, L. Zhang, K. Zhang, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

In the merge with motion vector difference (MMVD) mode, fractional distances including 1/4-pel and 1/2-pel are included in the distance table. However, fractional distances maybe inefficient for screen contents. To address this issue, this contribution proposes to disable fraction distances adaptively in MMVD mode. When fractional distances are disabled, distances in the default table are all multiplied by 4. Simulation results reportedly show 0.76% and 1.66% luma BD-rate saving on SCC sequences in Random Access configuration and Low Delay B configuration respectively. When CPR is off, 1.58% and 2.74% luma BD-rate saving on SCC sequences are achieved in Random Access configuration and Low Delay B configuration respectively.

More related to MMVD (not SCC). A similar approach was investigated in CE 4.4.5b (see remarks there), where switching to an integer table was proposed for UHD resolution.

Initially discussed Fri 11 afternoon in track B -> move to CE4 BoG.

[JVET-M0726](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5555) Cross-check of JVET-M0255 (AHG11: MMVD without Fractional Distances for SCC) [A. Karabutov (Huawei)] [late]

[JVET-M0326](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5133) CE8-related: Remove the redundancy of CPR-related syntax coding [S. Ye, F. Chen, L. Wang (Hikvision)]

This document proposes to remove the redundancy of CPR-related syntax coding. CPR-P frame is called for one frame where the current picture is the only reference picture. In fact, it is not allowed to use MMVD (Merge with MVD), Affine, merge triangle mode or Combined inter merge / intra prediction (CIIP) mode in the CPR-P frame. Therefore, this contribution proposes to remove those unused tools related syntax coding for CPR blocks in the CPR-P frame. By doing so, a small gain for luma BD rate of 0.01% was observed on AI configuration.

Similar to JVET-M0175. See notes there.

[JVET-M0615](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5435) Crosscheck of JVET-M0326 (CE8-related: Remove the redundancy of CPR-related syntax coding) [Y.-C. Sun (Alibaba)] [late]

[JVET-M0327](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5134) CE8-related: A new CPR syntax scheme [S. Ye, F. Chen, L. Wang (Hikvision)]

This document describes a new CPR syntax scheme.

In the VTM3.0, the current (partially) decoded picture is considered as a reference picture. This current picture is put in the last position of reference picture list 0. Therefore, for a frame using the current picture as the only reference picture, it is a P frame. To distinguish it with traditional P frame, we denoted it as a CPR-P frame. The bitstream syntax follows the same syntax structure for inter coding while the decoding process is unified with inter coding. The only outstanding difference is that the block vector (which is the motion vector pointing to the current picture) always uses integer-pel resolution.

The reported BD rate changes from the VTM3.0 with CPR enabled are as follows:

Scheme 1(Using initial context values of I frame for CPR-P frame):

* In AI, -0.05%/-0.05%/-0.02% for CTC/Class F/SCC 1080p classes, separately.

Scheme 2(Remain the frame type as I frame if the original frame type is I):

* In AI, -0.05%/-0.08%/-0.04% for CTC/Class F/SCC 1080p classes, separately.

Scheme 3(Take CPR as an intra mode in IBP frame):

* In AI, -0.09%/-0.17%/-0.39% for CTC/Class F/SCC 1080p classes, separately.

Presentation deck to be uploaded.

From the discussion, it is generally agreed that it would be much more desirable to handle CPR as a separate mode, and remove the signalling via reference picture list, and not use a P picture for that purpose. For VVC, there is no need to design it the same way as in HEVC (in HEVC, P picture was re-used, as CPR was defined in a later stage).

This would also resolve the problem of prohibiting combination with other MC tools

It is however desirable to re-use building blocks from MC.

JVET-M0327 does not come with a syntax proposal.

JVET-M0483 goes a similar direction. See further notes on that contribution.

[JVET-M0616](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5436) Crosscheck of JVET-M0327 (CE8-related: A new CPR syntax scheme) [Y.-C. Sun (Alibaba)] [late]

[JVET-M0333](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5140) Non-CE8: Coding on block vector difference [J. Nam, J. Lim, S. Kim (LGE)]

This contribution proposes a block vector difference coding for CPR mode. Considering that the absolute value of block vector difference (i.e., abs\_mvd\_minus2) for CPR mode is larger than that of conventional motion vector difference, higher order (K is equal to 3) of Exp-Golomb code is applied. From experiment results, following luma BD-rate changes are observed over VTM-3.0 with CPR:

* AI: -0.02% (CTC), -0.19% (Class F), -0.41% (SCC)
* RA: 0.00% (CTC), -0.27% (Class F), -0.10% (SCC)
* LD: 0.00% (CTC), -0.15% (Class F), -0.76% (SCC)

This would require a different binarization in the context of MV coding. During discussion in a JVET plenary about importance of consistency between CPR and MV coding whether we would encourage such low level changes, it was agreed that they could be done if they provide sufficient benefit. This proposal should be studied in CE to exercise such a case, though it remains tbd what “sufficient” means in case of screen content.

It is noted that the same statement applies to methods that had been investigated in CE8.1, provided they deliver similar gain.

[JVET-M0705](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5528) Crosscheck for JVET-M0333: Non-CE8: Coding on block vector difference [X. Xu (Tencent)] [late]

[JVET-M0334](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5141) Non-CE8: Removal of redundant syntax between CPR and other inter coding tools [J. Nam, J. Lim, S. Kim (LGE)]

When CPR tool is enabled in SPS, I-Slice is treated as P-Slice so that all syntax elements of the picture are signaled as P-Slice instead of I-Slice. Considering that current CPR mode does not work with some inter coding tools, such as MMVD, affine, multi-hypothesis, and tri-angular prediction, this contribution proposes to remove redundant syntax from those inter coding tools. Specifically, when the current decoded picture is the only reference picture for the current slice, syntax elements for inter coding tools, which does not work with CPR mode, is not signaled. From experiment results, following luma BD-rate changes are observed over VTM-3.0 with CPR:

* AI: -0.01% (CTC), -0.01% (Class F), -0.07% (Class SCC)
* RA: 0.00% (CTC), -0.03% (Class F), -0.06% (Class SCC)

Same as JVET-M0175 method 2. See further notes there.

[JVET-M0767](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5598) Crosscheck of JVET-M0334 (Non-CE8: Removal of redundant syntax between CPR and other inter coding tools) [X. Xu (Tencent)] [late]

[JVET-M0335](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5142) Non-CE8: modification on SbTMVP process regarding with CPR [H. Jang, J. Nam, S. Kim, J. Lim (LGE)]

In VTM-3.0, SbTMVP and TMVP are not allowed when fetched motion vector in collocated picture uses collocated picture itself as reference picture (i.e., fetched colPb is CPR coded). In current VVC specification, however there may be a coding unit, which is coded by PRED\_BI with L0 referring current picture and L1 previous decoded picture as reference. In this case, SbTMVP and TMVP, which is bi-predicted mode, is supposed to be operated based on motion vector of L1. Therefore, in this proposal, SbTMVP and TMVP are to be disallowed when the picture corresponding to L0 reference index of ColPb is collocated picture. The proposed method shows 0.00% and 0.00% BD-rate change in RA and LDB respectively.

It is the opinion of other experts that somehow the usage is restricted in VVC draft 3.

Anyway, if CPR would be defined as a separate mode, the issue would be resolved anyway.

[JVET-M0706](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5529) Crosscheck for JVET-M0335 Non-CE8: modification on SbTMVP process regarding with CPR [X. Xu (Tencent)] [late]

[JVET-M0341](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5148) Non-CE8: MMVD harmonization with CPR [H. Jang, J. Nam, S. Kim, J. Lim (LGE)]

This contribution presents a simplified MMVD considering CPR mode. When the current decoded picture is the only reference picture for the current slice, mmvd\_merge\_flag is not signalled and also 4 indices for mmvd\_distance\_idx are allowed. From experimental results, following BD-rate changes are observed over VTM-3.0 with CPR:

* AI: -0.03% (CTC), -0.13% (Class F), -0.3% (Class SCC)
* RA: -0.01% (CTC), -0.07% (Class F), -0.13% (Class SCC)

There is no conceptual reason to disable the combination of CPR and MMVD. There are other proposals (JVET-M0541). Furthermore, there is also relation with proposals which suggest similar action (alternative integer precision MVD table), e.g. JVET-M0255.

Further study.

[JVET-M0768](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5599) Crosscheck of JVET-M0341 (Non-CE8: MMVD harmonization with CPR) [X. Xu (Tencent)] [late]

[JVET-M0393](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5200) Non-CE8: chroma block vector initialization for CPR in dual tree [T. Poirier, F. Le Léannec, F. Galpin (Technicolor)]

This contribution describes a method to initialize chroma block vectors when dual tree is enabled and collocated luma block uses CPR partially. The method is implemented on top of VTM-3.0 with chroma subpel interpolation activated. The method is reported to result in PSNR-Y, U, V BD-rate variations of -0.01%, 0.00%, -0.01% with 100% and 99% encoding and decoding times in AI configuration, 0%, -0.01%, -0.03% with 100% and 100% encoding and decoding times in RA configuration.

Further results in the document show somewhat higher gains for class TGM.

There are two aspects: subpel chroma (4-tap) and determination of a chroma CPR vector in case of dual tree when no luma vector is available.

With dual tree enabled (which is CTC and also been known to be most beneficial in combination with CPR), it gives 0.3% for class TGM, 0.1% for class F. This is rather low, does not justify the additional complexity (e.g. determining and checking the derived vector, interpolation).

[JVET-M0751](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5582) Crosscheck for JVET-M0393: Non-CE8: chroma block vector initialization for CPR in dual tree [X. Xu (Tencent)] [late] [missing at end of meeting]

[JVET-M0402](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5210) Non-CE8: Proposed Cleanup for Current Picture Referencing [B. Heng, M. Zhou, W. Wan (Broadcom)]

The following document discusses some potential issues with the current picture referencing (CPR) tool. It provides a few different proposals for changes that would help reduce the likelihood that the tool is used in unintended or invalid ways. Specifically:

* Separate intra-picture CPR offsets from inter-picture motion vectors.
  + Signal CPR mode with explicit cpr\_flag rather than reusing ref\_idx.
  + Treat CPR as intra for existing motion vector prediction.
  + Explore separate CPR vector prediction that actually generates legal CPR vectors.
* Modified handling of illegal CPR vectors.
  + Add required clipping for any CPR vectors that point outside the current CTU.
  + Initialize not-yet-decoded pixels to some pre-defined value.
* Syntax modification for illegal dual-tree chroma CPR.
  + Prevent illegal usage of chroma CPR when underlying luma CU do not use CPR mode by modifying the syntax to make it impossible.

The contribution has different aspects.

- It supports an approach to define CPR as a separate mode. This also makes it simpler to define which other tools can be combined with it

- It suggests a decoder-side mechanism to preserve the valid range of MVs

- It suggests a decoder-side mechanism to ignore a CPR flag in chroma tree if any of the colocated luma blocks does not use CPR.

There is no concrete syntax/semantics proposal associated with the proposal.

Needs further consideration (probably in future meetings)

The current approach of imposing bitstream constraints is probably viable (and sufficient for the time being), but it might be safer to provide some “sanity check” at the decoder. Whether such a check needs to be normative or not needs still to be determined. Furthermore, we cannot describe the exact decoder behaviour upon an illegal bitstream, because it is impossible to check conformance.

[JVET-M0409](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5217) Non-CE8: Mismatch between text specification and reference software on ATMVP candidate derivation when CPR is enabled [X. Xu, X. Li, S. Liu (Tencent), W.-J. Chien, M. Karczewicz (Qualcomm)]

This contribution provides a specification aligned CPR software implementation regarding ATMVP CU level MV offset derivation. In a previous VVC specification, when performing alternative temporal motion vector prediction (ATMVP), a motion offset at CU level is obtained from the motion vector of the first available spatial neighboring merge candidate that has the collocated picture as its reference picture. In BMS2.1, if a neighboring merge candidate is coded in CPR mode, it is considered as not available. This implementation is inherited into VTM3.0 as part of CPR mode. In the current VVC specification, only the first available spatial candidate in the merge list will be checked. If the candidate doesn’t satisfy the condition of ATMVP neighboring block requirement, zero motion vector will be used to derive the collocated block in the collocated picture. Therefore, there is a mismatch between the specification and software implementation. Simulation results report that when the provided specification aligned implementation is compared to VTM-3.0 anchor (CPR=1):

* BD rate changes are 0.00%/0.00%/ 0.00% in AI/RA/LB configurations, respectively, for CTC average.
* BD rate changes are 0.00%/-0.01%/ -0.10% in AI/RA/LB configurations, respectively, for Class F.
* BD rate changes are 0.00%/-0.03%/ -0.10% in AI/RA/LB configurations, respectively, for SCC TGM class.

There are no apparent runtime changes observed.

Decision (SW/BF): Adopt JVET-M0409 (align software with text)

[JVET-M0732](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5561) Crosscheck of JVET-M0409 (Non-CE8: Mismatch between text specification and reference software on ATMVP candidate derivation when CPR is enabled) [T.-S. Chang, Y.-C. Sun, J. Lou (Alibaba)] [late]

[JVET-M0410](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5218) Non-CE8: CPR flag signaling at slice level [X. Xu, X. Li, S. Liu (Tencent)]

This contribution proposes to control the usage of CPR at slice level, in addition to the current CPR SPS flag. That means, when CPR SPS flag is true, for each slice, an encoder can choose to turn on or off the usage of CPR. On top of this change, an encoder algorithm is provided in a way that when the hash hit rate of a picture is below a certain threshold, the slice level CPR is turned off. The intent of the suggested algorithm is that CPR mode is turned off for slices where CPR may not contribute much to the BD rate reduction while CPR mode is turned on for screen content materials. Simulation results report that:

* The BD rate/runtime changes for CTC average are -0.01%/-0.01%/0.13% and 103%/101%/103% for AI/RA/LB, separately, when compared to VTM-3.0+CPR=0 anchor;
* The BD rate/runtime changes for Class F average are 0.13%/0.07%/0.03% and 96%/100%/99% for AI/RA/LB, separately, when compared to VTM-3.0+CPR=1 anchor
* The BD rate/runtime changes for Class SCC 1080p average are 0.00%/0.00%/0.01% and 98%/101%/98% for AI/RA/LB, separately, when compared to VTM-3.0+CPR=1 anchor

No urgent need to do this currently – for CTC, the usage of the sequence level flag is good enough.

[JVET-M0670](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5491) Crosscheck of JVET-M0410 (Non-CE8: CPR flag signaling at slice level) [J. Nam (LGE)] [late]

[JVET-M0411](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5219) Non-CE8: Inter mode related flag signaling when current picture is the only reference picture [X. Xu, X. Li, S. Liu (Tencent)]

This contribution proposes not to signal the following inter coding related flags in condition that the current picture is the only reference picture for a slice. Specifically, sub-block merge flag, affine flag, mmvd flag and intra-inter flag are not signaled. Simulation results report that BD rate changes are negligible (within +-0.1%) when compared to VTM-3.0 anchor (CPR=1).

No need for further discussion – see notes under JVET-M0175.

[JVET-M0635](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5455) Crosscheck of JVET-M0411 (Non-CE8: Inter mode related flag signaling when current picture is the only reference picture) [C.-Y. Lai (MediaTek)] [late]

[JVET-M0417](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5226) CE8-related: Combination test of CE8.2.2 and CE8.2.5 [Y.-C. Sun, J. Lou (Alibaba)]

This document reports the results of the combination of CE8.2.2 (palette mode and intra mode combination) and CE8.2.5 (separated palette design for the joint CUs containing both luma and chroma CBs). The tests are performed on top of CE8.2.1 (JVET-M0050). Compared with CE8.2.1, when the method is tested with CPR turned off in the setting, the results of the combination show that:

1. For 4:2:0 TGM sequences, the proposed method provides 2.5%, 2.8%, and 3.0% BD-rate gains for luma with 92%, 99% and 98% for encoding time, and 101%, 97% and 92% in decoding time under AI, RA, and LD configurations, respectively.
2. For Class F sequences, the proposed method provides 0.3%, 0.5%, and 1.5% BD-rate gains for luma, with 100%, 99% and 99% for encoding time, and 101%, 98% and 97% in decoding time under AI, RA, and LD configurations, respectively.

When the method is tested with CPR turned on in the setting,

1. For 4:2:0 TGM sequences, the proposed method provides 0.9%, 1.3%, and 2.4% BD-rate gains for luma with 95%, 99% and 100% for encoding time, and 100%, 98% and 100% in decoding time under AI, RA, and LD configurations, respectively.
2. For Class F sequences, the proposed method provides 0.0%, 0.2%, and 0.9% BD-rate gains for luma, with 99%, 100% and 103% for encoding time, and 100%, 101% and 98% in decoding time under AI, RA, and LD configurations, respectively.

It’s worthwhile to note that, compared with the results of CE8.2.2 and CE8.2.5 individually, the results of the proposed combination show further synergy between CE8.2.2 and CE8.2.5.

The contribution shows that palette has some subjective benefit.

Goal is to further improve palette over the basis configuration. Further study.

[JVET-M0556](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5369) Crosscheck of JVET-M0417 (CE8-related: Combination test of CE8.2.2 and CE8.2.5) [C.-Y. Lai (MediaTek)] [late]

[JVET-M0791](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5622) Crosscheck of JVET-M0417 (CE8-related: Combination test of CE8.2.2 and CE8.2.5) [Y.-W. Chen (Kwai Inc.)] [late]

[JVET-M0418](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5227) CE8-related: Context modeling on pred\_mode\_flag when current picture is the only reference picture (CPR) [Y.-C. Sun, J. Lou (Alibaba)]

This document modifies context modeling for pred\_mode\_flag signalling in VTM-3.0. Three methods are proposed to add new context models based on CU luma/chroma type and CU size. Compared with VTM-3.0 with CPR turned on, under AI configuration, the results show that:

1. Method 1 provides 0.2% and 0.0% BD-rate gains for luma for 4:2:0 TGM and Class F sequences, respectively.
2. Method 2 provides 0.4% and 0.1% BD-rate gains for luma for 4:2:0 TGM and Class F sequences, respectively.
3. Method 3 provides 0.5% and 0.2% BD-rate gains for luma for 4:2:0 TGM and Class F sequences, respectively.

It is proposed to have different context models for 4x4 and other luma CUs, and for CUs in luma/chroma trees (method 3 makes both cases different and shows highest coding gain).

This would only apply for CPR in intra picture, inter picture case is not changed.

For non-screen content sequences and COR turned on, all methods show loss for non screen content classes, compared to the existing context modelling.

No action.

[JVET-M0711](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5534) Crosscheck of JVET-M0418 (CE8-related: Context modeling on pred\_mode\_flag when current picture is the only reference picture (CPR)) [S. Ye (Hikvision)] [late]

[JVET-M0419](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5228) CE8-related: Context modeling on palette mode flag [Y.-C. Sun, J. Lou (Alibaba)]

This document modifies context modeling for palette flag signaling of CE8.2.1. Compared with CE8.2.1, the results of the proposed method show that, under AI configurations, the proposed method provides 0.1% and 0.1% BD-rate gains for luma for 4:2:0 TGM when the method is tested with CPR turned off and on, respectively.

Relative low gain in terms of TGM

[JVET-M0557](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5370) Crosscheck of JVET-M0419 (CE8-related: Context modeling on palette mode flag) [C.-Y. Lai (MediaTek)] [late]

[JVET-M0449](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5258) CE8-related: BDPCM entropy coding with reduced number of context coded bins [M. Xu, X. Li, X. Xu, M. Gao, S. Liu (Tencent)]

Block DPCM (BDPCM) is tested in CE8.3 and shown noticeable gains. For each residual sample, up to 12 bins are coded with context. A restriction is proposed to improve the entropy coding throughput, where up to 2 context coded bins are allowed for each sample on average. It shows almost no loss on CTC for AI and RA. Compared to the original method, it shows 0.09% and 0.13% BD-rate loss on average for class F in AI and RA configurations, respectively, and 0.12% and 0.32% BD-rate loss on average for class SCC in AI and RA configurations, respectively.

Presentation deck to be uploaded.

Further study (see also notes under CE8.3)

BDPCM plus palette was used in the results of this contribution. Generally, different combinations of enabling/disabling the various screen content specific tools should be studied to identify which gain they still provide when not used standalone.

[JVET-M0648](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5469) Crosscheck of JVET-M0449 (CE8-related: BDPCM entropy coding with reduced number of context coded bins) [F. Henry, G. Clare (Orange)] [late]

[JVET-M0464](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5273) Non-CE8: Unified Transform Type Signalling and Residual Coding for Transform Skip [B. Bross, T. Nguyen, P. Keydel, H. Schwarz, D. Marpe, T. Wiegand (HHI)]

This contribution proposes two modifications related to transform type signalling and residual coding for transform skip. The first modification includes aligning the cases in which transform skip (TS) and multiple transform selection (MTS) apply. This limits TS to luma transform blocks as well as extends it to transform block sizes up to 32x32. The second modification constitutes of a modified transform coefficient level coding for the TS residual. Relative to the regular residual coding case, the residual coding for TS includes no signalling of the last x/y position, coded\_sub\_block\_flag coded for every subblock, sig\_coeff\_flag context modelling with reduced template, a single context model for abs\_level\_gt1\_flag and par\_level\_flag, context modeling for the sign flag, additional greater than 5, 7, 9 flags, modified Rice parameter derivation for the remainder binarization and a limit for the number of context coded bins per sample. The proposed joint signalling (first modification) provides on average (BD-rate Y, enc. time, dec.time):

* Natural: 0.01%, 103%, 101% (AI), -0.02%, 98%, 100% (RA), -0.07%, 102%, 102% (LB)
* Class F: -1.96%, 103%, 97% (AI), -2.14%, 98%, 100% (RA), -2.79%, 103%, 99% (LB)
* TGM: -8.04%, 106%, 88% (AI), -8.74%, 106%, 96% (RA), -9.21%, 112%, 97% (LB)

Additionally changing the residual coding for transform skip (first modification and second modification) results on average in (BD-rate Y, enc. time, dec.time):

* Natural: -0.16%, 103%, 100% (AI), -0.07%, 98%, 101% (RA), -0.07%, 101%, 101% (LB)
* Class F: -7.16%, 104%, 94% (AI), -5.76%, 98%, 100% (RA), -5.85%, 102%, 99% (LB)
* TGM: -21.03%, 108%, 82% (AI), -15.57%, 105%, 94% (RA), -14.01%, 111%, 95% (LB)

v2 provides updated full frame results, details about the combined TS/MTS encoder search with results for different encoder operation points as well as draft text for unified TS/MTS syntax.

v3 corrects wrongly pasted results to match with the cross-check provided in JVET-M0708.

The aspect on TS/MTS in the proposal signals TS before MTS (and therefore also enables it for blocks up to 32x32), but also changes the MTS binarization

Results of TS modification are on top of VTC, would be desirable to see benefit for SC classes when CPR is on

There is also an aspect of encoder speedup, by another approach of early skip for testing MTS cases.

The modified coding method employs max 8 context coded bins per sample – much higher than current VVC limit.

The way of restricting the number of context coded bins (once the budget is consumed, TS is not used any more) is not elegant.

Question is raised whether it has subjective quality impact?

It is dicussed whether the aspect of signalling TS before MTS (and by that way enabling TS for block sizes up to 32x32, but also restricting it to luma) would rather be a straightforward syntax cleanup, which could be adopted at this meeting (but without modifying the MTS index binarization, which is discussed in CE6).

Later, results with a CPR-on anchor were reported. It was demonstrated that large-block TS still provides a benefit for screen content (1.6%, 4.9% for F/TGM in AI, 1.7%, 5.9% for LD). The adoption is reported elsewhere (from Track A).

[JVET-M0650](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5471) Crosscheck of JVET-M0464 (Non-CE8: Unified Transform Type Signaling and Residual Coding for Transform Skip, test TSRC-CCB8) [F. Henry, G. Clare (Orange)] [late]

[JVET-M0708](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5531) Crosscheck of JVET-M0464 (Non-CE8: Unified Transform Type Signaling and Residual Coding for Transform Skip, test TS32Y/uniMTS) [T. Tsukuba (Sony)] [late]

[JVET-M0834](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5665) Crosscheck of JVET-M0464 (Non-CE8: Unified Transform Type Signalling and Residual Coding for Transform Skip, test TSRC-CCB3 and CCB2) [S. Yoo, J. Lim (LGE)] [late]

[JVET-M0483](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5293) CE8-related: CPR mode signaling and interaction with inter coding tools [W.-J. Chien, V. Seregin, M. Karczewicz (Qualcomm)]

This contribution proposes two schemes to align the interaction between CPR mode with all other inter coding tools. The method is implemented on top of VTM-3.0 with CPR enabled. The first scheme removes CPR dependency in motion derivation process. It results in negligible BD-rate difference for all test configurations on regular or screen content materials. The second scheme uses CPR mode as a third mode other than intra or inter modes. Motion predictor for CPR mode and inter mode would be derived mutual-exclusively from each other. The simulations show 1.1% in RA configuration and 1.5% in LDB configuration in screen content coding materials.

(see also discussion under JVET-M0327)

In track B, the general consensus is that it is a right direction to signal CPR as a separate mode rather than using a special reference picture index. As this is a fundamental conceptual decision, this was later discussed and decided in the JVET plenary.

JVET-M0483 comes with spec text (“method 3”), which would probably need more careful inspection and modifications (also alignment with v9 of VVC draft 3).

This was further discussed in Track B Thursday 17 Jan 1730.

Generally, consensus that the text is appropriate. Open issues are raised as follows:

- How to implement HMVP? It is agreed that separate HMVP buffers (5 candidates each) should be used for conventional MV and IBC.

- How to implement merge? Share same process as in regular MV merge, but disallow TMVP, 0 vector means unavailable as it is invalid

- Constraints to be implemented in bitstream, no invalid vectors, merge shall not be used if the merge candidate is invalid (out of range or 0)

- For deblocking, IBC is handled as inter mode

- CIIP does not use IBC

- AMVP does not use quarterpel.

- In dual tree, the mode is signalled both for luma and chroma, same derivation of chroma vector as in VTM3.

For the time being, the VTM4 encoder uses a maximum block size of 16x16, which may be released in the future. No normative impact.

Decision: Adopt JVET-M0483 (text in zip v4, “r1”, probably needs some more update along the lines above).

[JVET-M0860](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5691) Cross check of JVET-M0483 [K. Misra (Sharp Labs of America)] [late]

[JVET-M0541](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5354) Non-CE8: Combination of MMVD and CPR mode [Y. Li, Z. Chen (Wuhan Univ.), X. Xu, S. Liu (Tencent)] [late]

This document describes unification methods of CPR merge mode with MMVD expansions. In the proposed methods, merge candidates with default merge type (MRG\_TYPE\_DEFAULT\_N) and CPR merge type (MRG\_TYPE\_CPR) may both exist in the MMVD candidate list. Thus CPR will not be excluded when MMVD is used. It is reported that the BD rate can be improved by enabling CPR with MMVD expansions.

Several methods are proposed, such as clipping the fractional pel offset into integer values. The average BD rate gain is around 0.3% for TGM, and 0.1% for class F in AI. Similar gain was reported in JVET-M0341.

Further study.

[JVET-M0542](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5355) Non-CE8: Combination of Multi Hypothesis Intra and CPR mode [Y. Li, Z. Chen (Wuhan Univ.), X. Xu, S. Liu (Tencent)] [late]

This document proposes to unify the CPR mode operation with multi hypothesis intra mode. In the proposed method, a multi-hypothesis can be a combination of intra mode and CPR merge mode. Thus CPR mode is unified with inter mode coding when multi hypothesis intra mode tool is used. It is reported that the BD rate changes by enabling CPR with multi-hypothesis intra mode are negligible.

The contribution shows that it would not be a problem to release the current bitstream constraint of disallowing combination of CPR and CIIP. On the other hand, results show that it obviously does not give benefit in terms of compression performance.

May be obsolete if CPR would be a separate mode.

[JVET-M0696](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5518) Crosscheck of JVET-M0542 (Non-CE8: Combination of Multi Hypothesis Intra and CPR mode) [T. Poirier (Technicolor)] [late]

[JVET-M0544](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5357) Non-CE8: CPR with chroma 4x4 sub-block size when dual-tree is on [X. Xu, X. Li, S. Liu (Tencent)] [late]

This contribution proposes to unify the handling of chroma sub-block size for CPR mode to that of inter sub-block mode (4x4), when dual-tree is enabled for CPR. For each group of four 2x2 chroma sub-blocks in a chroma CU under dual-tree condition, the collocated luma block vector of the top-left 2x2 chroma sub-block is used to derive the chroma block vector for all four sub-blocks. Simulation results report that:

* The BD rate changes for CTC average are 0.00%/0.00%/0.00% when compared to VTM-3.0+CPR=1 anchor
* The BD rate changes for Class F average are 0.06%/0.11%/0.07% when compared to VTM-3.0+CPR=1 anchor
* The BD rate changes for Class SCC 1080p average are 0.57%/0.25%/-0.08% when compared to VTM-3.0+CPR=1 anchor

Does not have advantage for CPR, as due to the integer precision of displacement vectors the 2x2 subblocks are no problem. It causes loss, and there may even be the possibility of luma/chroma mismatch e.g. at edges.

[JVET-M0669](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5490) Crosscheck of JVET-M0544 (Non-CE8: CPR with chroma 4x4 sub-block size when dual-tree is on) [J. Nam (LGE)]

[JVET-M0634](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5454) Affine motion mode in intra coding [S. Cao, H. Han, J. Wang, F. Liang, Y. Yu, Y. Liu] [late]

This was discussed in Track A Thursday night 1115-1130 (GJS & F. Bossen) – picked up by Track A to ensure presentation before the meeting ended.

In the contribution, the results of affine motion mode in intra coding are reported. This proposed technique combines the affine motion mode with current picture referencing (CPRAffine). The use of CPRAffine is signalled by using a reference picture index pointing to this current reference picture. In this way, the syntax structure and decoding process of CPRAffine mode are aligned with the regular intra mode. The proposed test reportedly shows BD-rate gain under AI for VTM anchors are:

-0.08%/-0.06%/-0.00% for Y, U, V component of Class F, separately.

The runtime impact was reported as 213%. This is clearly not a good tradeoff, but it was commented that there might be some issue with how this is implemented. Further study was suggested to determine whether there is some problem with the implementation.

[JVET-M0765](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5596) CE8-related: Unified Screen Content and Multiview Video Coding – Experimental results [J. Samelak, M. Domański] [late]

The HEVC standard provides separate screen-content and multiview profiles. Application of the multiview coding technology provides some gains over simulcast video coding of multiple views. Unfortunately, the multiview video coding technology was adopted in the limited number of applications only. On the other hand, the frame compatible approach to compress stereoscopic video was quite common recently. Moreover, the technology of Screen Content Coding seems to be successful in real-word applications. In this paper, we provide a modification HEVC Screen Content Coding that exhibits roughly the same coding efficiency as HEVC SCC and MV-HEVC for graphics and frame-compatible multiview content, respectively.

Current development of CPR (as needed for screen content) would not fulfil the requirements for FC multiview, as it has only integer precision and does not access the entire picture. For future stereo/multiview, frame compatible may no longer the main stream, as it penalizes spatial resolution, and it may be better to keep the pictures separate.

[JVET-M0822](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5653) Non-CE8: Encoder optimization for palette mode [H. Wang, Y.-H. Chao, V. Seregin, M. Karczewicz (Qualcomm)] [late]

This contribution proposes an encoder optimization for palette mode. The results show more than 20% encoding time reduction for AI for screen content sequences. When tested with CPR enabled, the partial results show that the encoding time is reduced from 157% to 115% with only 0.14% (Y) BD rate loss for TGM420 sequences, and the encoding time is reduced from 174% to 151% with 0.11% (Y) BD rate loss for class F.

Early termination criteria are used to avoid full checking of all intra modes if palette mode shows good performance (i.e. testing palette before intra modes but after CPR). Further, termination criteria for not testing palette are applied for areas that are too small (which also avoids checks in partitioning).

In the setup of the CE, this might be considered as becoming part of the CE software (for the palette basis configuration 8.2.1).

[JVET-M0835](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5666) Crosscheck of JVET-M0822 (Non-CE8: Encoder optimization for palette mode) [Y.-C. Sun (Alibaba)] [late]

[JVET-M0878](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5709) CE8-Related: A combination of Test CE8.1.3 and Test CE8.1.2d [L. Pham Van, T. Hsieh, V. Seregin, W.-J. Chien, M. Karczewicz (Qualcomm)] [late]

TBP (B)

## CE9 related – Decoder-side motion vector derivation (13)

Contributions in this category were initially assigned to Track B and were discussed in BoG JVET-M0858 unless otherwise noted.

[JVET-M0063](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4865) Non-CE9: An improvement of BDOF [T. Chujoh, T. Ikai (Sharp)]

[JVET-M0652](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5474) Crosscheck of JVET-M0063 (Non-CE9: An improvement of BDOF) [K. Choi (Samsung)] [late]

[JVET-M0073](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4875) Non-CE9: On early termination for BIO [K. Kondo, M. Ikeda, T. Suzuki (Sony)]

[JVET-M0813](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5644) Cross-check of JVET-M0073: Non-CE9: On early termination for BDOF [S. Bandyopadhyay (InterDigital)] [late]

[JVET-M0077](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4880) CE9-related: Relaxation of block size restriction for DMVR [K. Unno, K. Kawamura, S. Naito (KDDI)]

[JVET-M0567](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5380) Crosscheck of JVET-M0077 (CE9-related: Relaxation of block size restriction for DMVR) [T. Chujoh (Sharp)] [late]

[JVET-M0078](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4881) CE9-related: Combination of JVET-M0077 and CE9.2.5 [K. Unno, K. Kawamura, S. Naito (KDDI), T. Chujoh, T. Ikai (Sharp)]

[JVET-M0636](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5456) Cross-check of JVET-M0078 (CE9-related: Combination of JVET-M0077 and CE9.2.5) [Y. Kato, K. Abe, T. Toma (Panasonic)] [late]

[JVET-M0148](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4956) Non-CE9: Simplifications to DMVR search pattern and interpolation for refinement [S. Sethuraman (Ittiam)]

[JVET-M0506](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5317) Crosscheck of JVET-M0148 (Non-CE9: Simplifications to DMVR search pattern and interpolation for refinement) [X. Chen (HiSilicon)] [late]

[JVET-M0223](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5030) Non-CE9: Co-existence analysis for DMVR with BDOF [S. Sethuraman (Ittiam)]

[JVET-M0797](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5628) Crosscheck of JVET-M0223 (Non-CE9: Co-existence Analysis for DMVR with BDOF) [C.-C. Chen, W.-J. Chien (Qualcomm)] [late]

[JVET-M0241](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5048) CE9-related: A simple gradient calculation at the CU boundaries for BDOF [H. Lee, J. Kang, S.-C. Lim, J. Lee, H. Y. Kim (ETRI)]

[JVET-M0568](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5381) Crosscheck of JVET-M0241 (CE9-related: A simple gradient calculation at the CU boundaries for BDOF) [T. Chujoh (Sharp)] [late]

[JVET-M0249](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5056) Non-CE9: Modifications on Bi-Directional Optical Flow [H. Liu, L. Zhang, K. Zhang, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-M0731](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5560) Crosscheck of JVET-M0249 (Non-CE9: Modifications on Bi-Directional Optical Flow) [T.-H. Li, Y.-C. Yang (Foxconn)] [late]

[JVET-M0284](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5091) CE9-related: BDOF Modifications to Enable 64x64 VPDU [H. Chen, X. Ma, S. Esenlik, H. Yang, J. Chen (Huawei)]

[JVET-M0486](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5296) Cross-check of JVET-M0284: CE9-related: BDOF Modifications to Enable 64x64 VPDU [S Bandyopadhyay (InterDigital)] [late]

[JVET-M0316](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5123) CE9-related: simplification of BDOF [J. Li, R.-L. Liao, C. S. Lim (Panasonic)]

[JVET-M0701](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5523) Cross-check of JVET- M0316 (CE9-related: simplification of BDOF) [J. Zhao (LGE)] [late]

[JVET-M0516](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5327) Non-CE9.2.1.e: Non-local-mean-based MRSAD and Row-subsampled Search Pattern for DMVR [C.-C. Chen, W.-J. Chien, M. Karczewicz (Qualcomm)]

[JVET-M0577](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5391) Crosscheck of JVET-M0516 (Non-CE9.2.1.e: Non-local-mean-based MRSAD and Row-subsampled Search Pattern for DMVR) [S. Esenlik (Huawei)] [late]

[JVET-M0517](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5328) Non-CE9: Methods for BDOF complexity reduction [S. Sethuraman (Ittiam)]

[JVET-M0796](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5627) Crosscheck of JVET-M0517 (Non-CE9: Methods for BDOF Complexity Reduction) [C.-C. Chen, W.-J. Chien (Qualcomm)] [late]

[JVET-M0890](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5721) CE9-related: BDOF buffer reduction and enabling VPDU based application [H. Chen, X. Ma, S. Esenlik, H. Yang, J. Chen (Huawei), K. Kondo, M. Ikeda, T. Suzuki] [late]

TBP (B)?

[JVET-M0893](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5724) Crosscheck of disabling early termination in JVET-M0890 (CE9-related: BDOF buffer reduction and enabling VPDU based application) [T. Chujoh, T. Ikai (Sharp)] [late]

[JVET-M0896](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5727) Crosscheck of JVET-M0890 (CE9-related: BDOF buffer reduction and enabling VPDU based application) [Y.-W. Chen (Kwai Inc.)] [late]

## CE10 related – Combined and multi-hypothesis prediction (44)

Contributions in this category were initially assigned to Track B and were discussed in BoG JVET-M0873 unless otherwise noted.

[JVET-M0082](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4885) CE10-related: Simplification of Multi hypothesis intra prediction [Y. Kato, K. Abe, T. Toma (Panasonic)]

[JVET-M0808](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5639) Cross-check result of JVET-M0082 (CE10-related: Simplification of Multi hypothesis intra prediction) [K. Kawamura, S. Naito (KDDI)] [late]

[JVET-M0088](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4891) CE10-related: LIC restriction for pipeline structure [K. Abe, T. Toma (Panasonic)]

[JVET-M0371](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5178) Crosscheck of JVET-M0088 (CE10-related: LIC restriction for pipeline structure) [P. Bordes (Technicolor)] [late]

[JVET-M0096](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4900) CE10.1-related: Inter-intra prediction [L. Pham Van, G. Van der Auwera, A. K. Ramasubramonian, V. Seregin, M. Karczewicz (Qualcomm)]

[JVET-M0681](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5503) Crosscheck of JVET-M0096 (CE10.1-related: Inter-intra prediction) [F. Galpin, T. Poirier (Technicolor)] [late]

[JVET-M0115](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4920) CE10-related: pipeline reduction for LIC and GBI [P. Bordes, F. Galpin, T. Poirier (Technicolor)]

[JVET-M0570](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5383) Crosscheck of JVET-M0115 (CE10-related: pipeline reduction for LIC and GBI) [T. Chujoh (Sharp)] [late]

[JVET-M0118](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4923) CE10-related: A fix for merge triangle flag signaling [R. Yu (Ericsson)]

[JVET-M0631](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5451) Crosscheck of JVET-M0118 (CE10-related: A fix for merge triangle flag signalling) [M.-S. Chiang (MediaTek)] [late]

[JVET-M0182](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4989) CE10-related: Simplification of local illumination compensation [C.-M. Tsai, C.-C. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0596](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5415) Crosscheck of JVET-M0182 (CE10-related: Simplification of local illumination compensation) [Y. Yasugi, T. Ikai (Sharp)] [late]

[JVET-M0183](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4990) CE10-related: Simplification of MPM generation for CIIP [M.-S. Chiang, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0693](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5515) Crosscheck of JVET-M0183 (CE10-related: Simplification of MPM generation for CIIP) [Z. Zhang, K. Andersson, R. Sjöberg (Ericsson)] [late]

[JVET-M0695](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5517) Crosscheck of JVET-M0183 (CE10-related: Simplification of MPM generation for CIIP) [K. Andersson (Ericsson)] [late] [missing at end of meeting]

[JVET-M0184](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4991) CE10-related: Simplification of triangle merging candidate list derivation [T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0729](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5558) Crosscheck of JVET-M0184 (CE10-related: Simplification of triangle merging candidate list derivation) [M. Winken (HHI)] [late]

[JVET-M0185](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4992) CE10-related: Syntax redundancy removal in triangle prediction [M.-S. Chiang, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0582](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5399) Cross-check of JVET-M0185 (CE10-related: Syntax redundancy removal in triangle prediction) [K. Andersson, R. Yu (Ericsson)] [late]

[JVET-M0190](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4997) CE10-related: Redundant syntax reduction for triangle prediction [Y. Ahn, D. Sim (Digital Insights)]

[JVET-M0749](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5580) Cross-check of JVET-M0190 (CE10-related: Redundant syntax reduction for triangle prediction) [S.-C. Lim, H. Lee, J. Lee, J. Kang (ETRI)] [late]

[JVET-M0194](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5001) CE10-related: Triangle Prediction Mode Harmonization [A. Tamse, M. W. Park, S. Jeong, M. Park, K. Choi (Samsung)]

[JVET-M0207](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5014) CE10-related: Joint optimizations of Triangular prediction unit mode and Multi-Hypothesis prediction mode [S. Jeong, M. W. Park, A. Tamse, M. Park, K. Choi (Samsung)]

[JVET-M0775](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5606) Crosscheck of JVET-M0207: CE10-related: Joint optimizations of Triangular prediction unit mode and Multi-Hypothesis prediction mode [L. Pham Van, W.-J. Chien, M. Karczewicz (Qualcomm)] [late]

[JVET-M0216](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5023) CE10-related: syntax clean-up on triangle prediction [L. Li, J. Nam, N. Park, H. Jang, J. Lim, S. Kim (LGE)]

[JVET-M0849](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5680) Crosscheck of JVET-M0216 (CE10-related: syntax clean-up on triangle prediction) [C. Rosewarne (Canon)] [late]

[JVET-M0224](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5031) CE10-related: Local illumination compensation simplifications [S. Bandyopadhyay, X. Xiu, Y. He (InterDigital)]

[JVET-M0714](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5537) Crosscheck of JVET-M0224 (CE10-related: Local illumination compensation simplifications) [P. Bordes (Technicolor)] [late]

[JVET-M0232](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5039) CE10-related: Simplification of CIIP Intra mode coding [Y.-W. Chen, X. Wang (Kwai Inc.)]

[JVET-M0552](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5365) Crosscheck of JVET-M0232 (Non-CE10: Simplification of CIIP Intra mode coding) [M.-S. Chiang (MediaTek)] [late]

[JVET-M0233](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5040) CE10-related: Triangle prediction merge list construction [X. Wang, Y.-W. Chen (Kwai Inc.)]

[JVET-M0674](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5495) Crosscheck of JVET-M0233 (Non-CE10: Triangle prediction merge list construction) [S. Esenlik (Huawei)] [late]

[JVET-M0234](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5041) CE10-related: Triangle prediction merge index coding [X. Wang, Y.-W. Chen (Kwai Inc.)]

[JVET-M0675](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5496) Crosscheck of JVET-M0234 (Non-CE10: Triangle prediction merge index coding) [S. Esenlik (Huawei)] [late]

[JVET-M0271](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5078) CE10-related: Merge list construction process for triangular prediction mode [L. Zhang, K. Zhang, H. Liu, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

[JVET-M0588](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5406) Crosscheck of JVET-M0271 (CE10-related: Merge list construction process for triangular prediction mode) [H. Dou, Z. Deng, L. Xu (Intel)] [late]

[JVET-M0276](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5083) CE10-related: MPM list alignment between CIIP and intra mode [J. Li, S. Wang, W. Gao (Peking University), L. Zhang, K. Zhang, H. Liu, J. Xu (Bytedance)]

[JVET-M0755](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5586) Crosscheck of JVET-M0276 (CE10-related: MPM list alignment between CIIP and intra mode) [Y.-W. Chen (Kwai Inc.)] [late]

[JVET-M0283](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5090) CE10-related: Reduction of motion predictor pruning in Triangle Merge mode [A. Robert, F. Le Léannec, T. Poirier, F. Galpin (Technicolor)]

[JVET-M0868](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5699) Crosscheck of JVET-M0283 (CE10-related: Reduction of motion predictor pruning in Triangle Merge mode) [A. Filippov, V. Rufitskiy (Huawei)] [late]

[JVET-M0296](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5103) CE10-related: Simplification on combined inter-intra mode prediction [B. Wang, S. Esenlik, A.M. Kotra, H. Gao, J. Chen (Huawei)]

[JVET-M0734](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5563) Crosscheck of JVET-M0296 (CE10-related: Simplification on combined inter-intra mode prediction) [L. Zhao (Tencent)] [late]

[JVET-M0317](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5124) CE10-related: Simplification of triangular prediction unit mode [R.-L. Liao, J. Li, C. S. Lim (Panasonic)]

On deblock aspect: See notes at the end of CE11 related section.

[JVET-M0710](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5533) Crosscheck of JVET-M0317 (CE10-related: Simplification of triangular prediction unit mode) [F. Chen (Hikvision)] [late]

[JVET-M0328](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5135) CE10-related: Simplified triangle prediction unit mode [F. Chen, L. Wang (Hikvision)]

[JVET-M0666](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5487) Crosscheck of JVET-M0328 (CE10-related: Simplified triangle prediction unit mode) [R.-L. Liao, C. S. Lim (Panasonic)] [late]

[JVET-M0329](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5136) CE10-related: Modified enabling condition for triangle prediction unit mode [F. Chen, L. Wang (Hikvision)]

[JVET-M0692](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5514) Crosscheck of JVET-M0329 (CE10-related: Modified enabling condition for triangle prediction unit mode) [S.H. Wang (Peking University), X. Zheng, S.S. Wang, S.W. Ma] [late]

[JVET-M0331](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5138) CE10-related: A simplification method for Multi-intra-inter mode scheme [L. Xu, F. Chen, L. Wang (Hikvision)]

[JVET-M0533](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5345) Crosscheck of JVET-M0331 (CE10-related: A simplification of inter prediction information derivation for Multi-intra-inter mode scheme) [X. Chen (HiSilicon)] [late]

[JVET-M0349](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5156) CE10-related: Simplification of triangle prediction merging candidate list derivation [X. W. Meng (Peking University), X. Zheng (DJI), S.S. Wang, S.W. Ma (Peking University)]

[JVET-M0742](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5573) Crosscheck of JVET-M0390 (CE-10: related multi-hypothesis with uni-directional inter prediction restriction) [H. Wang (Qualcomm)] [late]

[JVET-M0352](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5159) CE10-related: Simplification of triangular partitions [D. Park, Y. Yoon, J.-G. Kim (KAU), J. Lee, J. Kang (ETRI)]

[JVET-M0722](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5549) Crosscheck of JVET-M0352 (CE10-related: Simplification of triangular partitions) [G. Laroche (Canon)] [late]

[JVET-M0357](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5164) CE10-related: Reduction of the worst-case memory bandwidth and operation number of OBMC [Y. Kidani, K. Kawamura, K. Unno, S. Naito (KDDI)]

[JVET-M0828](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5659) Crosscheck of JVET-M0357 (CE10-related: Reduction of the worst-case memory bandwidth and operation number of OBMC) [Y.-C. Lin (MediaTek)] [late]

[JVET-M0390](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5198) CE10 related: Multi-hypothesis with uni-directional inter prediction restriction [T. Poirier, E. François, K. Naser (Technicolor)]

[JVET-M0742](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5573) Crosscheck of JVET-M0390 (CE-10: related multi-hypothesis with uni-directional inter prediction restriction) [H. Wang (Qualcomm)] [late]

[JVET-M0399](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5207) CE10-related: Modifications of Triangular PU Mode [H. Wang, W.-J. Chien, V. Seregin, Y.-H. Chao, H. Huang, M. Karczewicz (Qualcomm)]

[JVET-M0694](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5516) Crosscheck of JVET-M0399 (CE10-related: Modifications of Triangular PU Mode) [T. Poirier (Technicolor)] [late]

[JVET-M0424](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5233) CE10-related: On enhancement of 4-tap interpolation filters [M. Sychev, J. Chen (Huawei)] [late]

Initial upload rejected as a placeholder.

[JVET-M0752](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5583) Crosscheck of JVET-M0424 [A. Henkel (HHI)] [late]

[JVET-M0438](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5247) CE10-related: Size constraint on Triangular Prediction [J. Zhao, S. Kim (LGE)]

[JVET-M0663](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5484) Crosscheck of JVET-M0438 (CE10-related: Size constraint on Triangular Prediction) [C.-W. Kuo, R.-L. Liao, C. S. Lim (Panasonic)] [late]

[JVET-M0450](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5259) CE10-related: LIC inheritance restrictions and interaction with GBI [M. Xu, X. Li, X. Xu, S. Liu (Tencent)]

[JVET-M0454](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5263) CE10-related: Multi-Hypothesis Intra with Weighted Combination [A. Seixas Dias, G. Kulupana, S. Blasi (BBC)]

[JVET-M0610](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5430) Crosscheck of JVET-M0454 (CE10-related: Multi-Hypothesis Intra with Weighted Combination) [B. Wang (Huawei)] [late]

[JVET-M0492](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5302) CE10-related: Simplified multi-hypothesis intra-inter mode [L. Zhao, X. Zhao, X. Li, S. Liu (Tencent)]

[JVET-M0589](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5407) Crosscheck of JVET-M0492 (CE10-related: Simplified multi-hypothesis intra-inter mode) [H. Dou, Z. Deng, L. Xu (Intel)] [late]

[JVET-M0500](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5310) CE10-related: Unidirectional illumination compensation [V. Seregin, W.-J. Chien, T. Hsieh, N. Hu, M. Karczewicz (Qualcomm)]

[JVET-M0633](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5453) Crosscheck of JVET-M0500 (CE10-realated: Unidirectional illumination compensation) [K. Abe (Panasonic)] [late]

[JVET-M0525](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5336) CE10-related: Simplification of intra prediction in CIIP [P.-H. Lin, Y.-J. Chang (Foxconn)]

[JVET-M0578](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5392) Crosscheck of JVET-M0525 (CE10-related: Simplification of intra prediction in CIIP) [M.-S. Chiang (MediaTek)] [late]

[JVET-M0581](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5397) CE10-related: Bi-directional motion vector storage for triangular prediction [M. Bläser, J. Sauer (RWTH Aachen University)] [late]

[JVET-M0829](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5660) Crosscheck of JVET-M0581 (CE10-related: Bi-directional motion vector storage for triangular prediction) [H. Gao (Huawei)] [late]

[JVET-M0736](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5566) CE10-related: Triangular prediction with MMVD [M. Bläser, J. Sauer (RWTH Aachen University)] [late]

[JVET-M0830](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5661) Crosscheck of JVET-M0736 (CE10-related: Triangular prediction with MMVD) [H. Gao (Huawei)] [late]

[JVET-M0792](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5623) CE10-related: Combined test of multi-hypothesis inter prediction and OBMC [Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, C.-W. Hsu, C.-C. Chen, Y.-C. Lin, Y.-W. Huang, S.-M. Lei (MediaTek), X. Xiu, Y. He (InterDigital), M. Winken, H. Schwarz, D. Marpe, T. Wiegand (HHI)] [late]

[JVET-M0884](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5715) Crosscheck of JVET-M0792 (CE10-related: Combined test of multi-hypothesis inter prediction and OBMC) [Z. Deng (Intel)] [late]

[JVET-M0838](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5669) CE 10 related: M0390-M0096 combination [F. Galpin, T. Poirier, E. François (Technicolor)] [late]

[JVET-M0848](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5679) CE10 related Document: Speedups for Uniform Directional Diffusion Filters For Video Coding (JVET-M0042) [J. Rasch, A. Henkel, J. Pfaff, H. Schwarz, D. Marpe, T. Wiegand (HHI)] [late]

[JVET-M0851](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5682) CE10-related: Using inter merge list derivation for triangle mode [H. Wang, W.-J. Chien, V. Seregin, Y.-H. Chao, H. Huang, M. Karczewicz (Qualcomm), X. Wang, Y.-W. Chen (Kwai), T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek), A. Tamse, M. W. Park, S. Jeong, M. Park, K. Choi (Samsung)] [late]

TBP(B)

[JVET-M0883](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5714) CE10-related: Using regular merge index signaling for triangle mode [H. Wang, W.-J. Chien, V. Seregin, Y.-H. Chao, H. Huang, M. Karczewicz (Qualcomm), X. Wang, Y.-W. Chen (Kwai), T. Solovyev, S. Esenlik, S. Ikonin, J. Chen (Huawei), M. Xu, X. Li, S. Liu (Tencent)] [late]

[JVET-M0886](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5717) Crosscheck of JVET-M0883 (CE10-related: Using regular merge index signaling for triangle mode) [H. Liu (Bytedance)] [late]

## CE11 related – Deblocking (4)

Contributions in this category were discussed Monday 14 Jan. 1715–1815 (Track B chaired by JRO).

[JVET-M0103](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4908) Deblocking for multi-hypothesis intra inter prediction [K. Andersson, J. Enhorn, R. Yu, Z. Zhang, R. Sjöberg (Ericsson)]

Multi-hypothesis intra inter prediction can produce boundaries on both CU and sub-block level due to uniform scaling of intra and inter prediction samples. Currently no deblocking is applied for such boundaries in VVC when transform, motion or intra deblocking criterions are false. This contribution proposes to set the boundary strength to 1 for boundaries of multi-hypothesis intra inter prediction on an 8x8 grid such that the boundaries will be deblocked as other inter modes.

The proposed fix is claimed to produce better subjective quality especially noticeable at low bitrates. Reported Y/U/V BD-rates are -0.02%/-0.02%/0.03% for random access, 0.00%/-0.01%/-0.09% for low delay B and -0.05%/-0.07%/-0.34% for low delay P over VTM-3.0.

Currently, no deblocking is performed when there is a CIIP block and next to it an inter block with same motion vector. This should be corrected.

JVET-M0294 is targeting the same issue and was also discussed in this context.

[JVET-M0549](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5362) Crosscheck of JVET-M0103 (Deblocking for multi-hypothesis intra inter prediction) [C.-M. Tsai (MediaTek)] [late]

[JVET-M0294](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5101) CE10-related: Modification for blocks applied with Combined Inter-Intra prediction [B. Wang, A.M. Kotra, S. Esenlik, H. Gao, J. Chen (Huawei)]

This contribution proposes two modifications for blocks applied with combined inter-intra prediction (for simplification, these blocks are named as combined prediction blocks). The first modification occurs to MPM (Most Probable Mode) list construction, where combined prediction blocks are considered as inter blocks always. The second modification is applied for deblocking filter, where combined prediction blocks are considered as intra blocks in boundary strength derivation. Two solutions are proposed: the first solution applies modification only for MPM list construction, the second solution applies both modification of MPM list construction and boundary strength derivation. The BD-rate results over the VTM3.0 anchor are:

* -0.01% (RA), 0.01% (LDB), -0.04% (LDP) for luma component with the first solution
* 0.00% (RA), 0.00% (LDB), -0.07% (LDP) for luma component with the second solution

AI results are the same to the anchor as modifications have no effect on I frames, wherein no combined prediction blocks exist.

Similar to the previous but it is suggested to set boundary strength to 2, which would typically be used when one side of the boundary is intra. Furthermore, subblocks are not deblocked here.

Proponents of M0103 and M0294 were asked to come together and suggest a reasonable solution to fix this bug. It was later recommended to use BS2 at CU/TU boundary, whereas BS1 is used at motion subblock boundaries. The proponents were asked to provide a combined specification text.

[JVET-M0908](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5739) CE11-related: Specification text for combination of JVET-M0103 and JVET-M0294 [K. Andersson, J. Enhorn, R. Yu, Z. Zhang, R. Sjöberg, B. Wang, A.M. Kotra, S. Esenlik, H. Gao, J. Chen] [late]

This was presented in Track B Fri 18 Jan 0800. Text is available

Decision: Adopt JVET-M0908

[JVET-M0587](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5404) Crosscheck of JVET-M0294 (CE10-related: Modification for blocks applied with Combined Inter-Intra prediction) [K. Zhang (Bytedance)] [late]

[JVET-M0187](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4994) CE11-related: Long deblocking filters with reduced line buffer requirement and enhanced parallel processing accessibility [C.-M. Tsai, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

This contribution proposes two aspects of modifications on top of the CE11.1.3 long deblocking filters in JVET-M0186. In both VTM3.0 and CE11.1.3, deblocking can be performed at 8x8 grids and is skipped at non-8x8 grids. The maximum numbers of to-be-read luma samples on one side of an edge during deblocking are four and eight for VTM3.0 and CE11.1.3, respectively. The maximum numbers of to-be-modified luma samples on one side of an edge during deblocking are three and seven for VTM3.0 and CE11.1.3, respectively. In the first aspect, to keep the number of luma sample lines needed to be stored in the line buffer as low as that in VTM3.0, during vertical filtering across horizontal coding tree unit (CTU) boundaries, the maximum number of to-be-read luma samples above the horizontal CTU boundary is reduced from eight to four, and in addition, the maximum number of to-be-modified luma samples above the horizontal CTU boundary is set to three. In the second aspect, to better support parallel deblocking at multiple parallel subblock boundaries on 8x8 grids, during horizontal filtering across vertical subblock boundaries and vertical filtering across horizontal subblock boundaries, if a subblock coding mode is chosen on one side of the subblock boundary, the number of to-be-read luma samples on that side of the subblock boundary is reduced from eight to four, and in addition, the maximum number of to-be-modified luma samples on that side of the subblock boundary is set to three. It is reported that the proposed deblocking results in negligible changes in BD-rate and encoding time, and the decoding time increase is 3% for VTM3.0 common test condition (CTC) and for VTM3.0 CTC with adaptive loop filter (ALF) off.

Generally similar approach as in CE11.1.7/8 and CE11.1.5, to reduce number of line buffers at CTU boundary. Further, the issue of duplicate deblocking of subblock boundaries (as mentioned under CE11) is solved for 11.1.3, in a similar fashion as used in CE11.1.6/7/8.

This would probably be something worthwhile to do as bug fix on the CE proposal (respectively to save line buffers).

The issue is no longer relevant due to adoption of CE11.1.8.

[JVET-M0604](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5424) Crosscheck of JVET-M0187 (CE11-related: Long deblocking filters with reduced line buffer requirement and enhanced parallel processing accessibility) [A. M. Kotra (Huawei)] [late]

[JVET-M0336](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5143) Non-CE11: Considering boundary strength on CPR coded block boundary [H. Jang, J. Nam, S. Kim, J. Lim (LGE)]

This proposal presents boundary strength design on CPR coded block boundary. Specifically, following two methods for boundary strength design are suggested.

* Boundary strength is set to 0 when at least one of block is coded as CPR across the block boundary.
* Boundary strength is set to 0 when both block are coded as CPR and set to 1 when only one block is coded as CPR across the block boundary

The proposed method has been shown to provide visual quality improvement on computer generated video sequence where CPR mode occurs frequently.

It is obvious that for screen content, deblocking may not be optimum for certain cases. On the other hand, an encoder might just decide turning it off, and QP37 as shown here is no a typical operation point of screen content, as usually the target is high visual quality, and even low QP typically does not have realy high rates.

Not obvious that there is a problem and if yes, if the suggested solution is solving it.

Put the aspect of studying impact of various loop filters on screen content as a mandate for the screen content AHG.

[JVET-M0605](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5425) Crosscheck of JVET-M0336 (Non-CE11: Considering boundary strength on CPR coded block boundary) [A. M. Kotra (Huawei)] [late]

[JVET-M0339](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5146) CE11-related: subblock boundary filter at 8x8 Grid [H. Jang, J. Nam, S. Kim, J. Lim (LGE)]

This contribution proposes a modification on subblock boundary filtering on 8x8 grid. In order to filter all subblock boundaries on 8x8 grid, subblock boundaries where the current PU is not aligned with 8x8 grid are also filtered in the proposed method, 4x4 block boundaries for affine and 8x8 block boundaries for SbTMVP. The proposed method shows -0.01% BD-rate change for RA configuration and also gives subjective quality improvement on subblock boundaries.

This is another variant over CE11.2, which gives up the restriction that only when the CU boundary is on an 8x8 grid, the corresponding boundaries of underlying subblocks are not deblocked in current VTM. This still allows parallel processing.

The case happens when a 16-wide or 16-high unit is ternary split, and then the middle partition is split into subblocks. Questionable whether this would have any visual impact, in particular after experiencing that CE11.2 (with its current test settings) did not have any significant visual impact.

Not related to this contribution: One expert asked if we should not potentially give up the requirement of parallel processing (i.e. deblock in a sort of AVC style on a 4x4 grid), instead of imposing sophisticated rules when to deblock or not, depending on the block structure.

[JVET-M0606](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5426) Crosscheck of JVET-M0339 (CE11-related: subblock boundary filter at 8x8 Grid) [A. M. Kotra (Huawei)] [late] [miss]

JVET-M0317 has also an aspect deblocking for triangular partitions. It is however not evident that there is a problem that causes artifacts, and therefore imposing another condition in deblocking based on triangle mode may not be necessary.

After reviewing all contributions of this section and the CE11 viewing results, it was suggested to perform further CE study on CE11.2 aspects, but also include a study whether deblocking at subblock boundaries is necessary at all. This was intrduced in VVC draft 2 without considering if there is impact on visual quality.

Further, the question was raised if everything in terms of deblocking is aligned with the new adoption of SBT.

## CE12 related – Mapping functions (2)

Contributions in this category were discussed Saturday 12 Jan. 1800–1830 (chaired by GJS).

[JVET-M0109](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4914) CE12-related: block-based in-loop reshaping [E. François, C. Chevance, F. Hiron (Technicolor)]

This document describes a block-based implementation of the in-loop luma reshaping approach proposed in contributions JVET-L0246 and JVET-L0247. In-loop luma reshaping requires at the decoder two basic sample mapping operations: forward reshaping of the prediction signal, inverse reshaping of the reconstructed signal. Both operations are by default operated per sample, requiring a per-sample access to a look-up-table. In the proposed approach, the process is performed per block. For each 4x4 block, linear model parameters are computed from three luma values and their mapped version. The linear model is then applied to the block samples. The proposal results in PSNR-Y, U, V BD-rate variations compared to the VTM3.0 of -0.74%, 1.49%, 1.22% in AI configuration, -1.17%, 1.50%, 1.50% in RA configuration, -0.54%, 2.62%, 3.21% in LB configuration.

The described method does not perform quite as well as the per-sample look-up.

Some banding was reported for content with flat areas (esp. screen content).

Further work was encouraged to try to find some complexity reduction of the remapping process, although this scheme does not seem adequate as-is.

It was commented that for hardware it might actually be easier to do the per-sample processing, as this avoids the extra step of computing an average.

[JVET-M0580](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5396) Crosscheck of JVET-M0109 (CE12-related: block-based in-loop luma reshaping) [T. Lu, P. Yin (Dolby)] [late]

[JVET-M0640](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5460) CE12-related: in-loop reshaping with approximate inverse mapping function [E. Francois (Technicolor)] [late]

This contribution relates to the in-loop luma reshaping approach proposed in contributions JVET-L0246 and JVET-L0247. In-loop luma reshaping requires at the decoder two basic sample mapping operations: forward reshaping of the prediction signal, inverse reshaping of the reconstructed signal. In its current implementation, the forward mapping can be achieved on-the-fly per sample using simple operations, whereas inverse mapping requires more complex operations. In this contribution it is proposed to approximate the inverse mapping function using a piece-wise linear (PWL) model of limited size, each piece being defined per luma interval of fixed length, power of 2, so that simple shifting can be used to identify the interval containing the sample value to map. It is reported that for most of the natural sequences, the gain of in-loop reshaping an be preserved using the proposed approximation with a PWL model size of 32 elements. For class E, F and some HDR content, larger PWL model size is required.

As with the technique described in M0109, some artefacts and loss were observed, although further work was encouraged to try to find some complexity reduction of the remapping process, although this scheme does not seem adequate as-is.

[JVET-M0703](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5525) Crosscheck of JVET-M0640 (CE12-related: in-loop luma reshaping with approximate inverse mapping function) [T. Lu, P. Yin] [late]

## CE13 related – Coding tools for 360° omnidirectional video (8)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

[JVET-M0322](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5129) CE13-related: In-loop filters disabled across face discontinuities on PHEC with 2-pixel padding [Y. Sun, X. Huangfu, L. Yu (Zhejiang Univ.)] [late]

[JVET-M0810](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5641) Crosscheck of JVET-M0322 (CE13-related: In-loop filters disabled across face discontinuities on PHEC with 2-pixel padding) [P. Hanhart (InterDigital)] [late]

[JVET-M0323](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5130) CE13-related: Adaptive QP to improve subjective quality for PHEC [Y. Sun, X. Huangfu, L. Yu (Zhejiang Univ.)] [late]

[JVET-M0811](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5642) Crosscheck of JVET-M0323 (CE13-related: Adaptive QP to improve subjective quality for PHEC) [P. Hanhart (InterDigital)] [late]

[JVET-M0534](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5346) CE13-related: HEC with Pre-rotation + Adaptive Frame Packing (Test 4.2.a+4.1) [C. Pujara, A. Konda, A. Singh, R. Gadde, W. Choi, K. Choi, K.P. Choi (Samsung)] [late]

[JVET-M0645](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5465) Crosscheck of JVET-M0534 (CE13-related: HEC with Pre-rotation + Adaptive Frame Packing (Test 4.2.a+4.1)) [P. Hanhart (InterDigital)] [late]

[JVET-M0225](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5032) AHG8: On wrap around motion compensation [B. Choi, W. Feng, S. Liu (Tencent)] [late]

[JVET-M0368](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5175) AHG8: 360Lib support for chroma sample location in PHEC blending process [C.-H. Shih, Y.-H. Lee, J.-L. Lin, Y.-C. Chang, C.-C. Ju (MediaTek)]

[JVET-M0644](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5464) Crosscheck of JVET-M0368 (AHG8: 360Lib support for chroma sample location in PHEC blending process) [P. Hanhart (InterDigital)] [late]

[JVET-M0452](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5261) AHG8: Hemisphere cubemap projection format [J. Boyce, M. Dmytrychenko (Intel)] [late]

[JVET-M0547](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5360) 360° coding tools using uncoded areas [J. Sauer, M. Bläser (RWTH Aachen University)] [late]

[JVET-M0892](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5723) CE-13 related: Loop filter disabled across virtual boundaries [S.-Y. Lin, L. Liu, J.-L. Lin, Y.-C. Chang, C.-C. Ju (MediaTek), P. Hanhart, Y. He (InterDigital)] [late]

## Loop filtering tools (14)

Contributions in this category were discussed Sunday 13 Jan. 1530–1800 and Monday 14 Jan. 1600-1715 (Track B chaired by JRO).

[JVET-M0162](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4969) Adaptive loop filter with a maximum number of luma filters per slice constraint [C.-Y. Chen, Z.-Y. Lin, C.-Y. Lai, Y.-W. Huang, S.-M. Lei (MediaTek)]

This contribution proposes a “maximum number of luma filters per slice” constraint to adaptive loop filter (ALF) in order to reduce the storage of filter coefficients in the on-chip memory. In the current ALF design, up to 25 luma filters can be signalled and used in one slice, which requires one on-chip memory with size equal to 25 filters x 13 coefficients per filter x 8 bits per coefficient = 2600 bits. The proposed method is to constrain the number of luma filters per slice. When the maximum number of luma filters is reduced from 25 to 16, the BD-rates for AI, RA, and LB are 0.00%, 0.00%, and 0.00%, respectively and 36% on-chip memory of luma filter coefficients is saved. When the maximum number of luma filters is 12, the BD-rates for AI, RA, and LB are 0.01%, 0.01%, and -0.01%, respectively, and 52% on-chip memory of luma filter coefficients is saved. When the maximum number of luma filters is 8, the BD-rates for AI, RA, and LB are 0.04%, 0.04%, and 0.01%, respectively, and 68% on-chip memory of luma filter coefficients is saved.

Generally, not a big deal (low amount of memory saving, while possibly giving up flexibility). It is however argued by proponents that this becomes more relevant together with JVET-M0163.

[JVET-M0618](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5438) Crosscheck of JVET-M0162 (Adaptive loop filter with a maximum number of luma filters per slice constraint) [Y.-W. Chen (Kwai Inc.)] [late]

[JVET-M0163](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4970) Adaptive loop filter with history filters [C.-Y. Chen, Z.-Y. Lin, C.-Y. Lai, Y.-W. Huang, S.-M. Lei (MediaTek)]

This contribution proposes history filters in adaptive loop filter (ALF). The concept of history filters is to allow using history filters for the current slice to increase coding efficiency, where the history filters are decoded filters from previously decoded slices. When the maximum number of history filter set is five, where one filter set contains all signalled filters of one slice, BD-rate savings are 0.16% and 0.34% for RA and LB, respectively, and the required memory of history filter set storage is 1660 bytes (5 sets \* 25 luma filters per set \* 13 coefficients per luma filter \* 1 byte per coefficient + 5 sets \* 1 chroma filter per set \* 7 coefficients per chroma filter \* 1 byte per coefficient). To reduce the memory requirement, it is further proposed to apply history filters with the “maximum number of luma filters per slice” constraint in JVET-M0162. When the maximum number of luma filters per slice is reduced from 25 to 16, BD-rate savings are 0.16% and 0.33% for RA and LB, respectively, and the required memory size is 1075 bytes (65% of no constraint). When the maximum number of luma filters per slice is 12, BD-rate savings are 0.15% and 0.33% for RA and LB, respectively, and the required memory size is 815 bytes (49% of no constraint).

The proposal targets compression improvement by re-using filters from previous pictures. The argument of saving on-chip memory (as under JVET-M0162) is not fully understood, as it would be external memory that is needed to store the coefficients along with the refernce pictures.

The reduction in bit rate is relatively low, and the approach would introduce some additional dependency between parameters of pictures. The current design of coding ALF parameters independently for every picture is quite clean.

It was also asked how it is determined which filter to use. This is based on matching with the covariance matrix.

No action.

[JVET-M0619](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5439) Crosscheck of JVET-M0163 (Adaptive loop filter with history filters) [Y.-W. Chen (Kwai Inc.)] [late]

[JVET-M0164](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4971) Adaptive loop filter with virtual boundary processing [C.-Y. Chen, T.-D. Chuang, Z.-Y. Lin, C.-Y. Lai, Y.-W. Huang, S.-M. Lei (MediaTek)]

In the adaptive loop filter (ALF) of VTM3.0, 7x7 diamond filters with 4x4 block-based classification are used for luma, and a 5x5 diamond filter without classification is used for chroma, which induces seven luma sample line buffers and four chroma sample line buffers in ALF implementation at the decoder. In order to reduce the line buffer requirement, ALF with virtual boundary (VB) processing is proposed: when one sample located at one side of a VB is filtered, accessing samples located at the other side of the VB is forbidden. The originally required samples at the other side of the VB are replaced with padded samples. To accommodate deblocking filter (DF) and sample adaptive offset (SAO) in VTM3.0, the VBs are set as four luma lines and two chroma lines above CTU row boundaries. It is reported that ALF with VB processing results in 0.07%, 0.10%, and 0.11% BD-rates for AI, RA, and LB, respectively, while the VB processing can totally remove the line buffer requirement of ALF.

It is asked whether this might introduce artifacts that make the CTU structure visible. The proponents report that they include a weighted average after the filtering, where the original sample is superimposed in a weighted fashin with the filtered sample. It is reported that such an approach in the context of HEVC ALF was effective to avoid visibility of artifacts.

Generally, the reduction of line buffers is very desirable, and would also justify the reported compression loss. It would however definitely be necessary to assess if it might introduce viusal artifacts in the context of VVC and its ALF design.

Similar concept in JVET-M0301.

Investigate in CE, and this should include subjective testing

[JVET-M0730](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5559) Crosscheck of JVET-M0164 (Adaptive loop filter with virtual boundary processing) [T.-H. Li, P.-H. Lin (Foxconn)] [late]

[JVET-M0277](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5084) Fixes of enabling pcm\_loop\_filter\_disabled\_flag with pcm mode signalling under dual tree partition [L. Zhang, K. Zhang, H. Liu, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

In current VVC, PCM mode flags for luma and chroma components are signalled separately when dual tree partition is enabled. However, when the pcm\_loop\_filter\_disabled\_flag is enabled, determination of enabling/disabling SAO filtering process for chroma blocks is wrongly based on the signalled PCM mode flag for luma blocks. In addition, ALF is performed even when pcm\_loop\_filter\_disabled\_flag is true. In this contribution, these two issues are fixed wherein whether to filter a block is dependent on the signalled PCM mode flag for the associated color component. Simulation results reportedly show that there is no performance changes under common test conditions.

Decision (BF/text): Include disabling ALF as a third loop filter when the pcm\_loop\_filter\_disabled\_flag is set, as suggested in JVET-M0277.

Decision (BF/SW): Disable SAO and ALF in chroma part when dual tree is used and the flag is set, and disable ALF in luma part when dual tree is used and the flag is set, as suggested in JVET-M0277.

Some experts commented that it might be better to get rid of PCM mode, as it is hardly used in practical encoders. This issue was also shortly raised in the closing plenary; it could be an action item for future consideration.

[JVET-M0614](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5434) Crosscheck of JVET-M0277 (Non-CE: Fixes of enabling pcm\_loop\_filter\_disabled\_flag with PCM mode signalling under dual tree partition) [Y.-C. Sun (Alibaba)] [late]

[JVET-M0301](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5108) Non-CE: Loop filter line buffer reduction [A. M. Kotra, S. Esenlik, B. Wang, H. Gao, J. Chen (Huawei)]

The current contribution proposes a mechanism of reducing the line buffer requirement of ALF (adaptive loop filter). The contribution uses the concept of virtual boundaries (VBs) which are upward shifted horizontal CTU boundaries by “N” samples. Modified ALF block classification and modified ALF filtering are applied for the samples which are near the virtual boundary to reduce the number of line buffers required. Modified ALF block classification only uses the samples which are above the VB to classify the given 4 x 4 block which is above VB. Similarly for the classification of the 4 x 4 block below VB, samples belonging to the lines below the VB are used. Modified ALF filtering uses a combination of conditional disabling and truncated versions of the original ALF filter.

Objective results are as follows: Over VTM 3.0 Anchor, for the case when “N” is 4 (AI, RA, LDB, LDP): Luma BD-Rate of 0.07%, 0.09%, 0.08%, 0.07% with no increase in EncT and DecT.

Over VTM 3.0 Anchor, for the case when “N” is 6 (AI, RA, LDB, LDP): Luma BD-Rate of 0.10%, 0.12%, 0.16%, 0.16% with no increase in EncT and DecT.

In terms of virtual boundary, the method is following the same concept as M0164. It is however somehow different in how the classification for padded samples is determined.

Investigate in CE, and this should include subjective testing.

[JVET-M0553](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5366) Crosscheck of JVET-M0301 (Non-CE: Loop filter line buffer reduction) [C.-M. Tsai (MediaTek)] [late]

[JVET-M0353](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5160) In-loop filtering: Simplification of ALF coefficients merge [M. Ikeda, T. Suzuki (Sony)]

In this contribution, the simplification of ALF (Adaptive Loop Filter) coefficients merge is proposed. In VTM-3.0, ALF coefficients can be merged after deriving 25 sets of luma filter coefficients in order to reduce signaling bits overhead in encoder side. In the merge process, pairs of classification index to be merged are identified by an exhaustive search. In this contribution, three variants are presented, and they can simplify the process and provide the similar coding efficiency: variant1: AI 0.07%, RA 0.10% LDB 0.18%, variant2: AI 0.08%%, RA 0.11% LDB 0.15%, variant3: AI 0.07%, RA 0.09% LDB 0.17%, respectively.

The approach would simplify the syntax, but add a number of tables to describe which options of merging can be used (less flexible than the current method) Furthermore, all three methods give a loss. The benefit in runtime reduction is not visible. No action.

[JVET-M0728](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5557) Crosscheck of JVET-M0353 (Non-CE: Simplification of ALF coefficients merge Variant 3) [N. Hu (Qualcomm)] [late]

[JVET-M0724](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5551) Crosscheck of JVET-M0353 (Non-CE: Simplification of ALF coefficients merge) [G. Laroche, J. Taquet (Canon)] [late]

[JVET-M0385](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5192) Non-linear Adaptive Loop Filter [J. Taquet, C. Gisquet, G. Laroche, P. Onno (Canon)]

This contribution introduces an adaptive clipping operation on the input samples values of the Adaptive Loop Filter in VTM3.0. The goal of this adaptive clipping is to introduce some non-linearities to cap the difference between the input sample value to be filtered and the other neighbor input sample values of the filter.

Compared to VTM3.0, the average Luma/Cr/Cb BDR gains are reported to be -0.44%/-0.49%/-0.69% for the AI configuration, -0.70%/-1.00%/-1.04% for the RA configuration, -0.72%/-0.94%/-1.22% for the Low Delay B configuration, and -1.02%/-1.44%/-1.58% for the Low Delay P configuration.

The method requires 24 subtractions and 24 clipping operations per sample. Threshold values for clipping are determined by solving a linear equation system and using the covariance matrix, and are signalled (12 per luma filter, 6 per chroma filter). Encoder runtime is approx. unchanged, decoder runtime increases by roughly 30% on average.

Study in CE.

[JVET-M0766](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5597) Crosscheck of JVET-M0385 (Non-linear Adaptive Loop Filter) [M. Ikeda (Sony)] [late]

[JVET-M0428](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5237) Encoder optimization with deblocking filter [N. Hu, V. Seregin, W.-J. Chien, M. Karczewicz (Qualcomm)]

Deblocking filter is included in VTM-3.0 to apply to reconstructed pixels in order to reduce the blocking artifacts between blocks. However, the encoder of VTM-3.0 doesn’t apply the deblocking filter in rate distortion optimization (RDO). In this contribution, to enhance the coding performance, deblocking filter is applied during RDO, such that distortion is calculated between filtered reconstructed pixels and original ones. Test results reportedly show 0.58%, 0.71% and 0.66% luma gain with similar encoding and decoding time, in AI, RA and LDB configuration respectively over VTM-3.0 anchor.

Decision (SW): Adopt JVET-M0428, not for CTC.

Some CE might to use this for additional comparison exercising normative vs. non-normative optimizations.

However, when VVC performance is compared e.g. against HEVC, such tricks should not be used, or the HM should use such option as well.

[JVET-M0612](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5432) Crosscheck of JVET-M0428 (Encoder optimization with deblocking filter) [Y.-C. Sun (Alibaba)] [late]

[JVET-M0429](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5238) Coding tree block based adaptive loop filter [N. Hu, V. Seregin, H. Egilmez, M. Karczewicz (Qualcomm)]

[JVET-M0243](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5050) Cross-check of JVET-M0429 (Coding tree block based adaptive loop filter) [S.-C. Lim, J. Kang, H. Lee, J. Lee (ETRI)] [late]

In this proposal, the coding tree block (CTB) based ALF scheme proposed in JVET-K0382 and JVET-L0391 was tested in VTM-3.0. Test results reportedly show 0.16%, 0.51% and 0.67% luma gain with similar encoding and decoding time, in AI, RA and LDB configuration respectively over VTM-3.0 anchor.

Each CTU can select one out of 22 filter sets (16 fixed, 5 temporal, 1 picture optimized). The 16 fixed filters were optimized from HM encoded, range of qualities as in common test conditions.

As it was said before (see comments under JVET-M0163), the usage of temporal filter sets might be undesirable, as it introduces further dependency between pictures.

(It is noted that depending on possible alternatives how the filter parameters would be signalled in HLS, the above comment might need to be revised.)

It is also asked how the performance would be in non-CTC QP ranges, as the fixed sets were ptimized specifically for the CTC QPs.

Compared to previous proposals on this issue, the gain is similar, but the encoding complexity is not increased.

Study in CE, also considering the questions above, performance without temporal filters, lower QP range.

[JVET-M0461](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5270) Alternate ALF filter shapes for luma [D. Socek, A. Puri (Intel)]

In the contribution, it is proposed to modify luma filter shape for adaptive loop filter (ALF). In VTM3.0, the ALF shape for luma is fixed to 7x7 diamond (25 taps and 13 unique coefficients). Two modified luma ALF shapes are considered: (1) combined 7x7 diamond and 9x9 cross filter with fully symmetric outermost cross coefficient (29 taps and 14 unique coefficients, Figure 1a), and (2) combined 7x7 diamond and 9x9 cross filter with fully symmetric two outermost cross coefficients (29 taps and 13 unique coefficients). Alternate shapes are combined with TC offsets of -2 for LB and RA, and -6 for AI. It is reported that, compared to VTM3.0, the first alternate ALF luma shape (1) yields -0.57%, -0.17%, and -0.36% luma BD-rates for AI, RA, and LB, respectively, while the second ALF luma shape (2) yields -0.57%, -0.15%, and -0.34% luma BD-rates for AI, RA, and LB, respectively. There are minor runtime changes in the performed tests.

Presentation deck to be uploaded.

Beyond the filter shape change, Tc for deblocking is also change.

It is commented that the new filters would require two more line buffers which is undesirable. If combined with the methods of virtual CTU boundary processing, even more padding would be necessary than with the existing 7x7 filter, such that likely gain would be considerably reduced.

[JVET-M0468](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5278) Non-CE: Hadamard transform domain filter [S. Ikonin, V. Stepin, J. Chen (Huawei)]

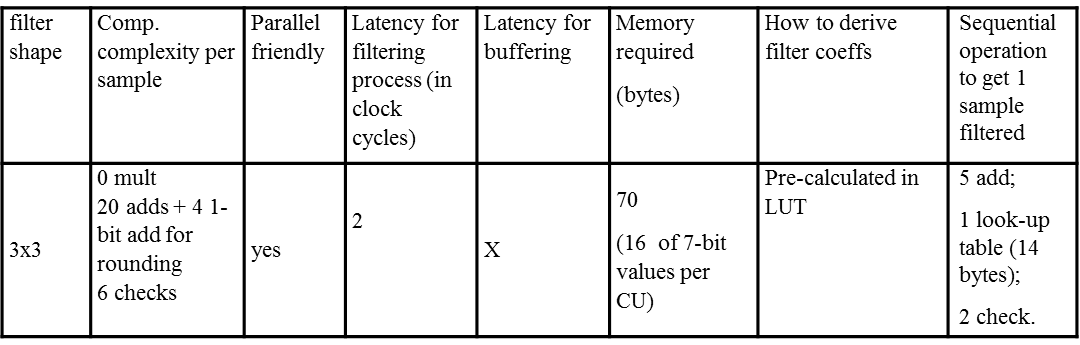
This contribution reports simulation results of post-reconstruction filter based on Hadamard transform similar to one tested in JVET-K-CE14.3b. Depending in filter appliance condition the simulations results over VTM-3.0 are:

* Test 1: For minimum block size 4x8 and 8x4: -0.50%/-0.72%/-0.58% of the luma BD-rate change with 106%/103%/102% of encoding time and 105%/101%/101% of decoding time for AI/RA/LDB configurations correspondingly.
* Test 2: For minimum block size 8x8: -0.37%/-0.64%/-0.50% of the luma BD-rate change with 105%/103%/101% of encoding time and 105%/101%/101% of decoding time for AI/RA/LDB configurations correspondingly.
* Test 3: For minimum block size 8x8 and filtering of inter blocks only: -0.39%/-0.40% of the luma BD-rate change with 102%/101% of encoding time and 101%/101% of decoding time for RA/LDB configurations correspondingly.

Test 1 and Test 2 are technology-wise identical to what had previously been investigated in CE14 before the 12th meeting, but after more analysis on the impact on intra prediction pipelining it had not been adopted.

Test 3 is new, only using the filter for inter blocks, and always using it when coefficients are coded (CBF=1), has gain of approx. 0.4% for both RA and LB. It is an additional processing stage, with complexity as per subsequent table (from BoG of last meeting):

[This table is a picture!]



It is pointed out that the filtering should also be disabled for CIIP and IBC, as this would have the same latency problem as intra prediction. Whereas it was said in the last meeting for another proposal (bilateral filter) that had similar latency problem for inter and only 0.4% for RA, it is interesting to note that the post-filtering gain seems still to be preserved in VTM3. It is also verbally reported that for the bilateral filter a new reduced complexity exists (at last meeting, BF was more complex than Hadamard domain filter). The proponents of BF announce that they intend to submit a late contribution on these changes.

It is discussed what the relation with other approaches, particularly diffusion filter would be. Each of those would add another stage in the pipeline of prediction, residual generation by inverse transform, etc., where one expert argues, that this pipeline should not be extended by too many steps. Complexity-wise, the diffusion filter is simpler in terms of number of operations per sample (however, has one multiplication), and a decision on that is still to be made.

During the discussion, it is questioned whether it would be better to enable switching at block level.

Further study in CE for Test 3 with constraint on CIIP and IBC, also version with block-level flag. It should also be tested how the performance is when it is outside of the loop, i.e. not used for predicting intra blocks (in which it could be applied somewhere before deblocking).

[JVET-M0787](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5618) Cross-check of JVET-M0468 (Non-CE: Hadamard transform domain filter) [J. Ström (Ericsson)] [late]

[JVET-M0842](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5673) Crosscheck of JVET-M0468 (Non-CE: Hadamard transform domain filter) [M. Salehifar (LGE)] [late]

[JVET-M0885](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5716) Non-CE: Reduced complexity bilateral filter [J. Ström (Ericsson)] [late]

TBP (B) – late contribution on bilateral filter when available.

[JVET-M0898](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5729) Crosscheck for JVET-M0885 (Reduced complexity bilateral filtering) [J. Rasch (HHI)] [late]

[JVET-M0894](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5725) Non-CE: Test on parametrizable bilateral filter from JVET-L0406 in VTM3.0 [M. Karczewicz (Qualcomm)] [late]

TBP(B)

[JVET-M0899](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5730) Cross-check of JVET-M0894 (Non-CE: Test on parametrizable bilateral filter from JVET-L0406 in VTM3.0) [S.-C. Lim, H. Lee, J. Lee, J. Kang (ETRI)] [late]

## General prediction aspects (0)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

## Quantization (8)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

[JVET-M0083](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4886) AHG10: Quantization matrices for MTS [T. Toma, K. Abe (Panasonic)]

[JVET-M0342](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5149) Crosscheck of JVET-M0083 (AHG10: Quantization matrices for MTS) [M. Ikeda (Sony)]

[JVET-M0105](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4910) Delta QP for Chroma CU [R. Chernyak, S. Ikonin, J. Chen (Huawei)]

[JVET-M0188](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4995) On quantization parameter signalling considering CU area [O. Chubach, T.-D. Chuang, C.-W. Hsu, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0707](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5530) Crosscheck for JVET-M0188: CE7-related: On quantization parameter signalling considering CU area [Y. Wang, X. Xu (Tencent)] [late]

[JVET-M0113](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4918) CE7-related: Quantization Group size uniformity [P. de Lagrange, E. François, P. Bordes (Technicolor)]

[JVET-M0114](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4919) CE7-related: implicit QP-offset based on block size [P. de Lagrange, E. François, F. Le Léannec (Technicolor)]

[JVET-M0119](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4924) CE7-related: Modified dequantization scaling [K. Sharman, S. Keating (Sony)]

[JVET-M0318](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5125) CE7-related: QP prediction and neighbour availability [P. de Lagrange, P. Bordes (Technicolor)]

[JVET-M0685](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5507) Non-CE7: On derivation of quantization parameter predictor [K. Misra, A. Segall (Sharp Labs of America)] [late]

## Entropy coding (1)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

[JVET-M0222](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5029) Context Reduction for CABAC in VVC [Y.-H. Chao, A. Said, V. Seregin, J. Dong, M. Karczewicz (Qualcomm)]

Discussed Thu 8pm. Chaired by FJB

No planned CE on context reduction.

Encouraged to resubmit in future meetings when cleaning up spec.

[JVET-M0617](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5437) Crosscheck of JVET-M0222 (Context Reduction for CABAC in VVC) [Y.-C. Sun (Alibaba)] [late]

## Tools based on NN technology (7)

Contributions in this category were discussed Monday 14 Jan. 1815–1945 (chaired by JRO).

[JVET-M0159](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4966) AHG9: Convolutional neural network loop filter [Y.-L. Hsiao, C.-Y. Chen, T.-D. Chuang, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

This document presents two modifications of convolution neural network loop filter (CNNLF) introduced in JVET-K0222. The first modification is to reduce two 4-layer networks separate for luma and chroma to only one 3-layer network shared by luma and chroma. The second modification is to conditionally signal the CNNLF parameters in the I-slice header. Compared with VTM3.0, the proposed CNNLF reportedly achieves -1.23% (Y), -10.11% (Cb), and -9.96% (Cr) BD-rates with 42% decoding time increase in random access (RA) condition without using any GPUs. After shifting coding gain from chroma to luma by increasing chroma quantization parameter (QP) offsets, the BD-rates are -2.47% (Y), +2.90% (Cb), and +3.01% (Cr). It is shown that Class C (small resolution, 832x480) has no coding gain because of the relatively “expensive” side information bits of CNNLF parameters while Class A (large resolution, 3840x2160) has higher coding gains (-3.7% luma BD-rate and +3% chroma BD-rate). Further research on CNNLF to reduce complexity and enhance training for improving coding efficiency is suggested.

It is assumed that the CNN parameters are offline trained per RA period.

Results with chroma QP offset are non-CTC, difficult to conclude something from that.

It is reported that the gain becomes lower for low resolution sequences such as class C, due to the higher relative amount of network parameters (which is about 10 kbit/s).

Software would be available.

[JVET-M0771](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5602) Crosscheck of JVET-M0159 (AHG9: Convolutional neural network loop filter) [H. Dou, Z. Deng, J. Boyce (Intel)] [late]

[JVET-M0215](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5022) AHG9-related: CNN-based lambda-domain rate control for intra frames [Y. Li, D. Liu, Z. Chen (USTC)]

This contribution proposes a CNN-based λ -domain rate control approach for intra frame coding. Compared with the exiting SATD-based intra rate control approach in VTM, the contribution reuses the R-lambda model in VTM inter frame rate control and train two convolutional neural networks to predict the model parameters, alpha and beta respectively. Compared with the rate control method in VTM 3.0, the proposed method can achieve an average bd-rate reduction of 2% under All Intra configuration. When considering the mismatch between target bitrate and actually coded bit rate, the CNN-based method can achieve a smaller rate control error, especially for the first I frame.

The uploaded presentation deck is different from the one shown in the presentation.

Approximately 5% run time increase compared to current rate control (CPU).

Software would be available. To be further studied in the AHG on NN technology.

Very interesting to see that NN based rate control can outperform conventional approaches, but extension of its applicability to other frames (e.g. predicting rates for the different levels of B picture hierarchy) would be desirable.

[JVET-M0907](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5738) Crosscheck of AHG9-related: CNN-based lambda-domain rate control for intra frames [X. Zheng, Y. Wang (DJI)] [late]

[JVET-M0351](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5158) Convolutional Neural Network Filter (CNNF) for Intra Frame [C. Lin, J. Yao, L. Wang (Hikvision)] [late]

Initial upload rejected as a placeholder.

This contribution provides a convolutional neural network filter (CNNF) for intra frames. In the current VTM, multiple filters, i.e., deblocking filter (DF) and sample adaptive offset (SAO) are used to remove artifacts or improve performance. CNNF is motivated by the latest advances in deep learning and is proposed as a single type of filter to replace multiple filters in intra frame. Simulation results report -4.94%, -7.07%, -8.17% BD-rate savings for luma, and both chroma components for VTM-3.0 with AI configuration.

Same method was proposed in JVET-I0022 (by that time run on top of JEM). Similar gain.

Software was already released by that time.

[JVET-M0743](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5574) Crosscheck of JVET-M0351 (AHG9: Convolutional Neural Network Filter (CNNF) for Intra Frame) [Y. Dai, D. Liu, Y. Li, F. Wu] [late]

[JVET-M0508](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5319) AHG9: Test Results of Dense Residual Convolutional Neural Network based In-Loop Filter [Y. Wang, Z. Chen, Y. Li (Wuhan Univ.), L. Zhao, S. Liu, X. Li (Tencent)]

This contribution reports the test results for dense residual convolutional neural network based in-loop filter (DRNLF) JVET-L0242 according to the methodology in JVET-L1006. The proposed DRNLF is implemented on VTM 3.0. Simulation results report -2.17%, -1.47%, -1.48% BD-rate savings for luma , and both chroma components compared with VTM 3.0 under AI configuration in CPU only platform, and -2.15%, -3.04%, -1.96% for RA configuration, and -2.06%, -3.73%, -2.86% for LDB configuration.

Operated between deblocking and SAO.

Different networks were trained specifically for the different QP values of CTC.

It is noted that it would be interesting to investigate how large the loss would be when used for another QP value.

Gain over VTM3 is slightly lower than it was for VTM2.

[JVET-M0510](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5321) AHG9: CNN-based in-loop filter proposed by USTC [Y. Dai, D. Liu, Y. Li, F. Wu (USTC)] [late]

This contribution presents the simulation results of an efficient network for loop filter. To reduce storage space and reduce complexity, we build two light weight deep convolutional neural networks by reduce network parameters. Simulation results report -0.96%, -0.32%, -0.45% BD-rate savings for Y, Cb, and Cr components compared with VTM3.0 under AI configuration, -0.61%, -0.25%, -0.26% for RA configuration, and -0.76%, -0.56%, -0.69% for LDB configuration.

Operated between deblocking and SAO.

For AI; Decoding time 21x/13x for the two versions used. For LB: 3-4x. Encoding time increases approx. 25%.

Can be enabled/disabled at CTU level.

Question: Does this produce visual artifacts?

[JVET-M0673](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5494) Crosscheck of JVET-M0510: AHG9: CNN-based in-loop filter proposed by USTC [F. Chen (Hikvision)] [late]

[JVET-M0566](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5379) Adaptive convolutional neural network loop filter [H. Yin, R. Yang, X. Fang, S. Ma, Y. Yu (Intel)] [late]

This document proposes an adaptive convolution neural network loop filter (ACNNLF) design. In this design, 3 CNN based loop filters are adaptively trained for luma and chroma respectively from the current video sequence. Each filter is a small 2 layer CNN with total 692 parameters. The encoder selects one of the three ACNNLFs for luma and chroma respectively for each CTB block during encoding. The weights of the trained set of ACNNLFs are signaled in the slice header of I frames and the index of selected ACNNLF is signaled for each CTB.

Compared with VTM-3.0-RA, the proposed ACNNLF achieves -2.37%, -1.34%, and -2.77% BD-rates for Y, U, and V, respectively, for Class A1 video sequences; -0.45%, -10.92%, and -6.19% BD-rates for Y, U, and V, respectively, for Class A2 video sequences; -0.49%, -11.29%, and -10.73% BD-rates for Y, U, and V, respectively, for Class B video sequences; and 0.12%, -3.31%, and -1.62% BD-rates for Y, U, and V, respectively, for Class C video sequences.

Operated after ALF (last loop filter)

Two different CNN for luma and chroma. At CTU level, it can be decided which out of three filters to use (or no filter). An additional weighting is signalled at slice level, which weights the residual that is generated by the network and superimposed.

The gain comes mainly from a few sequences (Campfire has the biggest gain).

[JVET-M0691](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5513) AHG9: Complexity analysis about neural network video coding tools [Y. Li, Z. Chen (Wuhan Univ.), S. Liu (Tencent)] [late]

To be reviewed in BoG.

[JVET-M0872](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5703) AHG9: A Result of Convolutional Neural Network Filter [K. Kawamura, S. Naito (KDDI)] [late]

This contribution contains a performance evaluation of the convolutional neural network filter proposed in JVET-L0383. Compared with the contribution in the previous meeting, the result in this meeting comes from not only intra picture but also from inter picture. Coding gain of Y BD-rates are -1.65% / -1.82% / 00.49% for all intra, random access, and low-delay B condition, respectively.

Previous contribution had only results on AI. Gains in AI over VTM3 are similar as they were over VTM2.

BoG on planning a CE on NN based loop filters (Yiming Li). The main target of that CE should be to investigate the impact of adaptation/switching (e.g. sequence basis, CTU basis, QP related); impact of position in the loop filtering chain; investigate performance and complexity of different architectures, etc.

## High-level syntax (53)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

### General high-level syntax and parameter sets (22)

[JVET-M0776](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5607) AHG17&AHG15: A summary of JVET-M contributions on general HLS [Y.-K. Wang (Huawei)] [late]

#### General high-level syntax and NAL unit header (11)

[JVET-M0101](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4906) AHG17: On VVC HLS [R. Skupin, K. Sühring, Y. Sanchez (HHI), M. M. Hannuksela, K. Kammachi-Sreedhar (Nokia), Y.-K. Wang, Hendry (Huawei), S. Wenger, B. Choi (Tencent), S. Deshpande (Sharp)]

[JVET-M0120](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4925) Proposed NAL Unit Header Design Principles [S. Wenger, B. Choi, S. Liu (Tencent)]

[JVET-M0131](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4936) AHG17: On NAL unit types for IRAP pictures and leading pictures [Y.-K. Wang, Hendry (Huawei)]

[JVET-M0152](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4959) AHG17: On random access point for VVC [B. Choi, S. Wenger, S. Liu (Tencent)]

[JVET-M0153](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4960) AHG17: On leading picture for VVC [B. Choi, S. Wenger, S. Liu (Tencent)]

[JVET-M0156](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4963) AHG17: On component type indication for VVC [B. Choi, S. Wenger, S. Liu (Tencent)] [late]

[JVET-M0157](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4964) AHG17: On picture order count for VVC [B. Choi, S. Wenger, S. Liu (Tencent)] [late]

[JVET-M0161](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4968) AHG17: Signalling random access properties in the NAL unit header [L. Chen, C.-W. Hsu, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0520](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5331) AHG17: On NAL unit header design for VVC [S. Wenger, B. Choi, S. Liu (Tencent)]

[JVET-M0529](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5340) AHG14: Normative Recovery Point Indication [M. Pettersson, R.Sjöberg, M. Damghanian (Ericsson)]

[JVET-M0537](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5349) AHG17: On tile group signaling in NAL unit header and as non-VCL NAL unit [E. Thomas, A. Gabriel (TNO)] [late]

#### Reference picture management (3)

[JVET-M0128](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4933) AHG17: On reference picture management for VVC [Y.-K. Wang, Hendry (Huawei), S. Deshpande (Sharp), M. M. Hannusela (Nokia), G. Ryu, W. Choi (Samsung), X. Wang, Y.-W. Chen (Kawi), L. Zhang (Bytedance), P. Wu, M. Li (ZTE), S.-H. Kim (LG), J. Boyce (Intel), A. M. Tourapis, D. Singer (Apple), F. Edouard, P. Andrivon (Technicolor), Y.-W. Huang, C.-W. Hsu, C.-Y. Chen, T.-D. Chuang, L. Chen (MediaTek), K. Kawamura (KDDI), Y.-C. Sun, J. Lou (Alibaba)]

After BoG discussion, this was discussed Sunday 13 January 1700 (GJS).

This contribution proposes a reference picture management approach for VVC based on direct signalling and derivation of reference picture lists 0 and 1, without use of reference picture set (RPS) as in HEVC or the sliding window plus memory management control operation (MMCO) process as in AVC.

It is asserted that the proposed approach is significantly simpler compared to the approaches in HEVC and AVC.

The proposed direct-RPL-based reference picture management approach is summarized as follows:

Two reference picture lists, list 0 and list 1, are directly signalled and derived. They are not based on RPS as in HEVC or the sliding window plus MMCO process as in AVC.

Reference picture marking is directly based on reference picture lists 0 and 1, utilizing both active and inactive entries in the reference picture lists, while only active entries may be used as reference indices in inter prediction of CTUs.

Information for derivation of the two reference picture lists is signalled by syntax elements and syntax structures in the SPS, the PPS, and the slice header. Predefined RPL structures are signalled in the SPS, for use by referencing in the slice header.

The two reference picture lists are generated for all types of slices, i.e., B, P, and I slices.

The two reference picture lists are constructed without using a reference picture list initialization process or a reference picture list modification process.

Long-term reference pictures (LTRPs) are identified by POC LSBs. When needed, additional POC LSBs are signalled for LTRPs, determined at a picture by picture basis.

In the discussion, a problem was identified with the POC MSB handling when considering random access that is not at the start of the first CVS in the “original” bitstream. Instead of signalling MSBs directly, it was suggested to use the scheme of HEVC with delta\_poc\_msb\_present\_flag[ i ] and delta\_poc\_msb\_cycle\_lt[ i ] (and remove the proposed additional MSB length syntax in the PPS).

In the discussion, it was noted that there should be a POC wrap-around prevention constraint for short-term pictures (see HEVC C.4 item 8). It was agreed that this is needed.

Decision: Adopt with modifications as described above.

[JVET-M0154](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4961) AHG17: On decoded picture buffer management for VVC [B. Choi, S. Wenger, S. Liu (Tencent)]

[JVET-M0378](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5185) AHG17: RPS for VVC [R. Sjöberg, M. Damghanian, M. Pettersson (Ericsson)] [late]

#### Picture header and header parameter set (HPS) (4)

[JVET-M0132](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4937) AHG17: On header parameter set (HPS) [Y.-K. Wang, Hendry, J. Chen (Huawei)]

[JVET-M0260](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5067) AHG17: Carriage of tile group header parameters in higher level structures [M. M. Hannuksela (Nokia)]

[JVET-M0377](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5184) AHG17: Picture header NAL unit type [R.Sjöberg, M. Damghanian, M. Pettersson (Ericsson)]

[JVET-M0415](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5224) AHG17: Comments on High-Level Syntax of VVC [S. Deshpande (Sharp)]

#### Miscellaneous general HLS topics (3)

[JVET-M0133](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4938) AHG17: On parsing dependency between parameter sets [Y.-K. Wang (Huawei), J. Boyce (Intel)]

[JVET-M0386](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5193) AHG17: On slice\_type (tile\_group\_type) [K. Sühring, Y. Sanchez, R. Skupin (HHI)]

[JVET-M0579](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5393) On Frame Rate Support and Extraction in VVC [A. Segall, S. Deshpande (Sharp Labs of America), M. Hannuksela (Nokia)]

### Interoperability and capability points definition and signalling (1)

[JVET-M0451](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5260) Update to interoperability point syntax [J. Boyce (Intel)]

### Tiling and tile partitioning (28)

[JVET-M0774](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5605) AHG12: A summary of JVET-M contributions on picture partitioning [Y.-K. Wang (Huawei), M. M. Hannuksela (Nokia)] [late]

#### Tiling allowing tile size unit less than CTU size (5)

[JVET-M0066](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4868) AHG12: Flexible Tile Partitioning [Y. Yasugi, T. Ikai (Sharp)]

[JVET-M0423](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5232) Cross-check of JVET-M0066: AHG12: Flexible Tile Partitioning [A. Wieckowski (HHI)]

[JVET-M0376](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5183) AHG12: On signaling of flexible tiles [M. Damghanian, R.Sjöberg, M. Pettersson (Ericsson)]

[JVET-M0459](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5268) AHG12: On tiles with partial CTUs [R. Skupin, K. Sühring, Y. Sanchez, T. Schierl (HHI)]

[JVET-M0527](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5338) AHG12: Comments on Tiles and Flexible Tile Partitioning [W. Wan, M. Zhou, T. Hellman, B. Heng, P. Chen (Broadcom)]

[JVET-M0875](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5706) Request for flexible unit size tile with implementation friendly restriction [T. Ikai, Y. Yasugi (Sharp), G. Bang (ETRI), Y.-W. Chen, X. Wang (Kwai Inc.), M. Coban (Qualcomm), C.-C. Lin (ITRI), P.-H. Lin (Foxconn), A. Ichigaya (NHK), K. Kawamura (KDDI), K. Kazui (Fujitsu), R. Sjöberg (Ericsson), R. Skupin, K. Sühring, Y. Sanchez, T. Schierl (HHI), L. Zhang (Bytedance)] [late]

This contribution proposes flexible unit size tile with certain restrictions, allowing tiling with tile size unit that is not a multiple of the CTU size. In the tile BoG, the implementation difficulty for less than CTU size and loop filter control for 360 video has been discussed. In this contribution, it is asserted that CTU alignment is too restricted to enable important tile use cases. It is also argued that the proposed specific restrictions alleviate the concerns implementation cost increase.

In JVET-M0066, the main part of this proposal had reportedly been implemented, tested and cross-checked. The software and working draft had been uploaded at 2018-12-28 05:28:56 and this was announced in the JVET main reflector at 2018-12-29.

The contribution reported the following points as the main difficulty for hardware implementation which could affect cost:

1. Throughput capability, i.e. Partial size CTUs could need the same time processing time as full size CTUs in pipeline processing.
2. Memory bandwidth / compression, i.e. temporal motion vector or other information needs to be transferred between internal memory and external memory via burst transfer.
3. Address generator, i.e. address generator needs more flexible calculation which depends on tile position.

The contribution proposed that the minimum unit granularity (TileUnitSizeY) be required to be 32 or larger.

A participant commented that if the 32x32 restriction is imposed, the desired functionality can be obtained with no special support in the standard, at a small loss of coding efficiency – by using 32x32 as the CTU size.

It was also commented that the 32x32 granularity is still restrictive and may not align with natural content boundaries.

The proponent showed some test results that indicated that the penalty of using 32x32 CTUs was large. Other participants questioned whether that penalty could really be that large. The data had not been cross-checked.

A participant commented that pipelining implementation requires fetching and processing data in large chunks with a regular structure that this would interfere with.

There were strong concerns about this expressed by some participants. It was said that the 32x32 CTU case is not as difficult because these come in strings.

Further study was encouraged. It was planned to ask AHG13 to measure the effect of CTU size on coding efficiency.

#### Flexible tiling (4)

Option 3 of M0261 is effectively another way to achieve the flexible tiling functionality, through dividing pictures into rectangular sub-pictures and each sub-picture may refer to its own PPS and may hence have its own tile partitioning.

[JVET-M0123](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4928) AHG12: On hierarchical tile design [Y. He, A. Hamza (InterDigital)]

[JVET-M0129](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4934) AHG12: On flexible tiling [Y.-K. Wang, Hendry, M. Sychev (Huawei)]

[JVET-M0374](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5181) AHG12: Flexible tiles to support MCTS use cases [R.Sjöberg, M. Damghanian, M. Pettersson (Ericsson)]

[JVET-M0530](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5341) AHG12: On signalling of tiles [M. Coban, M. Karczewicz (Qualcomm)] [late]

#### Rectangular tile grouping (5)

[JVET-M0121](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4927) AHG12: On Rectangular Tile Group [Y. He, A. Hamza (InterDigital)]

[JVET-M0130](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4935) AHG12: On tile grouping [Y.-K. Wang, Hendry, J. Chen, M. Sychev (Huawei)]

[JVET-M0160](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4967) AHG17: Flexible tile grouping for VVC [L. Chen, T.-D. Chuang, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0209](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5016) AHG12: On tile group configuration [W. Choi, K. Choi, K. Choi (Samsung)]

[JVET-M0416](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5225) AHG12: On Tile Information Signalling [S. Deshpande (Sharp)]

#### Tile and tile group identification and addressing (5)

[JVET-M0134](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4939) AHG12: On explicit signalling of tile IDs [Hendry, Y.-K. Wang, J. Chen, M. Sychev (Huawei)]

[JVET-M0155](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4962) AHG12: On tile group identification for VVC [B. Choi, S. Wenger, S. Liu (Tencent)] [late]

[JVET-M0373](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5180) AHG12: Merge friendly tile group address signalling [R.Sjöberg, M. Damghanian, M. Pettersson (Ericsson)]

[JVET-M0430](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5239) AHG12: On Tiles and Tile Groups for VVC [R. Skupin, K. Sühring, Y. Sanchez, T. Schierl (HHI)]

[JVET-M0853](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5684) AHG12: On Tile Grouping [S Deshpande (Sharp), Hendry, Y.-K. Wang (Huawei), M. M. Hannuksela (Nokia), Y. He (Interdigital), L. Chen (MediaTek), W. I. Choi (Samsung), B. D. Choi (Tencent), R. Sjöberg (Ericsson), R. Skupin (HHI)] [late]

#### MCTS and sub-picture sequence (5)

JVET-M0416 also includes one aspect on MCTS signalling in the PPS.

[JVET-M0261](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5068) AHG12: On grouping of tiles [M. M. Hannuksela, A. Aminlou (Nokia)]

[JVET-M0388](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5195) AHG12/AHG17: On merging of MCTSs for viewport-dependent streaming [M. M. Hannuksela (Nokia)]

[JVET-M0445](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5254) AHG12: On motion constrained tiles for VVC [R. Skupin, V. George, K. Sühring, Y. Sanchez, T. Schierl (HHI)]

[JVET-M0536](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5348) AHG12: On picture-level tiles and sequence-level tiles for VVC [E. Thomas, A. Gabriel (TNO)] [late]

[JVET-M0870](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5701) AHG12: Proposed JVET common test conditions and evaluation procedures for MCTS and sub-pictures with boundary padding [M. Coban (Qualcomm), R. Skupin (HHI)] [late]

Discussed Monday 1940 (GJS).

This document proposes common test conditions (CTC), conversion practices, and software reference configurations to be used in evaluation of MCTS and sub-picture coding schemes.

This is for coding efficiency testing. The suggested method is to encode and decode MCTSs separately and compute and substract the duplicate header overhead data quantity to measure results. Software decoder runtimes might not be properly measured that way, since that is not likely to match how the feature would be implemented. The tested use case is a cubemap projection 360° video source.

In Track A, it was suggested to make this a CE, since it was a plan for one specific test of a particular technology (see CE12).

#### Miscellaneous tiling topics (3)

[JVET-M0136](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4941) AHG12: Treating tile and tile group boundaries as picture boundaries [J. Chen, Y.-K. Wang, Hendry, M. Sychev (Huawei)]

[JVET-M0137](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4942) AHG12: On tile configuration signalling [M. Sychev, Hendry, Y.-K. Wang (Huawei)]

[JVET-M0375](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5182) AHG12: On uniform tile spacing [M. Damghanian, R.Sjöberg, M. Pettersson (Ericsson)]

### Wavefront parallel processing (2)

[JVET-M0070](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4872) AHG12: Wavefront processing in a tile group [T. Ikai, S. Deshpande, T. Chujoh, E. Sasaki, T. Aono (Sharp)]

[JVET-M0071](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4873) WPP: Improved parallel processing capability with WPP [Y. Fujimoto, M. Ikeda, T. Suzuki (Sony)]

[JVET-M0593](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5412) Crosscheck of JVET-M0071 (AHG12: Improved parallel processing capability with WPP) [Y. Yasugi, T. Ikai (Sharp)] [late]

# Complexity analysis and reduction (10)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

[JVET-M0245](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5052) AHG16-related: Chroma block coding and size restriction [C. Rosewarne, A. Dorrell (Canon)] [late]

Initial upload rejected as placeholder

[JVET-M0821](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5652) Crosscheck of JVET-M0245 (AHG16-related: Chroma block coding and size restriction) [T. Y. Zhou, T. Ikai (Sharp)] [late]

[JVET-M0065](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4867) Non-CE3: Intra chroma partitioning and prediction restriction [T. Zhou, T. Ikai (Sharp)]

[JVET-M0442](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5251) Crosscheck of JVET-M0065 (Non-CE3: Intra chroma partitioning and prediction restriction) [K. Zhang (Bytedance)] [late]

[JVET-M0169](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4976) CE3-related: Shared reference samples for multiple chroma intra CBs [Z.-Y. Lin, T.-D. Chuang, C.-Y. Chen, Y.-W. Huang, S.-M. Lei (MediaTek)]

[JVET-M0715](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5539) Crosscheck of JVET-M0169 (CE3-related: Shared reference samples for multiple chroma intra CBs) [X. Ma (Huawei)] [late]

[JVET-M0248](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5055) AHG16: Motion compensation with padded samples for small coding units [H. Liu, J. Chon, H.-C. Chuang, L. Zhang, K. Zhang, J. Xu (Bytedance)]

[JVET-M0607](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5427) Crosscheck of JVET-M0248 (AHG16: Motion compensation with padded samples for small coding units) [B. Wang (Huawei)] [late] [missing at end of meeting]

[JVET-M0265](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5072) AHG16: Clean-up on MV Rounding [K. Zhang, L. Zhang, H. Liu, J. Xu, Y. Wang, P. Zhao, D. Hong (Bytedance)]

This was discussed in Track A Wednesday 16 January 1600-1630 (GJS).

In VTM-3.0, MV averaging is performed by pair-wise merge candidate, triangular prediction and affine prediction for chroma components with different ways of rounding. It is proposed to unify the MV rounding operation to be the same as MV rounding in affine MV derivation. In addition, it is proposed not to clip MVs for the luma component before calculating the MV for chroma components in affine prediction, to align the VTM software and the working draft. Simulation results reportedly show 0.00% BD-rate change under Random Access (RA) configurations.

Decision: Change the software to match the WD to remove clipping of luma MVs before deriving chroma MVs.

It was reported that prior to VTM 3, there was only one rounding in MV averages.

Offset = 1 << (F-1);

M= S >= 0 ? (S + Offset) >> F: -((-S + Offset) >> F).

This is rounding away from zero. Some recent changes to VTM 3 were not consistent with that, and it was proposed to always use this same rule.

Decision (BF/consistency): Adopt rounding away from zero for MV averages.

[JVET-M0563](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5376) Cross-check of JVET-M0265 (AHG16: Clean-up on MV Rounding) [X. Chen (HiSilicon)] [late]

[JVET-M0864](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5695) [AHG5] Enhancement of cache model by adopting block-based format [R. Hashimoto, S. Mochizuki (Renesas)] [late]

[JVET-M0879](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5710) Crosscheck of JVET-M0864 ([AHG5] Enhancement of cache model by adopting block-based format) [T. Zhou, Y. Yasugi, T. Ikai (Sharp)] [late]

[JVET-M0045](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4846) Non-CE3: PDPC Restriction [S. Keating, K. Sharman (Sony)]

[JVET-M0561](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5374) Crosscheck of JVET-M0045 (Non-CE3: PDPC Restriction) [J. Lee, H. Lee, S.-C. Lim, J. Kang (ETRI)] [late]

[JVET-M0122](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4926) Non-CE3: On block size restrictions for PDPC [A. Filippov, V. Rufitskiy, J. Chen (Huawei)]

[JVET-M0880](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5711) Cross-check of contribution JVET-M0122, test 3.a (Non-CE3: On block size restrictions for PDPC) [F. Racapé (Technicolor)] [late]

[JVET-M0806](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5637) Cross-check of contribution JVET-M0122 (Non-CE3: On block size restrictions for PDPC) [M. Schäfer, J. Pfaff (HHI)] [late]

[JVET-M0238](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5045) Non-CE3: Modification of PDPC [J. Lee, H. Lee, S.-C. Lim, J. Kang, H. Y. Kim (ETRI)]

[JVET-M0678](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5500) Crosscheck of JVET-M0238 (Non-CE3: Modification of PDPC) [S. Keating (Sony)] [late]

[JVET-M0814](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5645) Non-CE3: block size restriction on PDPC [L. Li, J. Heo, J. Choi, S. Yoo, J. Choi, J. Lim, S. Kim (LGE)] [late]

[JVET-M0881](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5712) Crosscheck of JVET-M0814 (Non-CE3: block size restriction on PDPC) [A. Filippov, V. Rufitskiy (Huawei)] [late]

# Encoder optimization (3)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

[JVET-M0091](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4894) AHG10: Clean-up and finalization of perceptually optimized QP adaptation method in VTM [C. Helmrich (HHI)]

Presented Thu 8:20pm. Chaired by FJB

This contribution proposes a clean-up and a completion of the perceptually optimized QP adaptation (QPA) algorithm already integrated into the VTM codec software.Specifically, the following points are addressed:

1. for HD and smaller input sequences, the previously employed reduction of the CTU size is removed
2. for HD and smaller input, a depth-1 QPA (4 QPs per CTU) is used instead of the CTU size reduction
3. the QPA parameter pic is now defined as a function of the picture size instead of by a case-statement
4. an extension of the QPA algorithm for better visual handling of CTUs with glaring colors is provided
5. some remaining obsolete QPA related is code removed and some DC offset calculations are unified.

The proposed changes, whose integration into the next VTM software version is suggested, result in slightly reduced bitstream sizes for HD or smaller sequences and the *Campfire* UHD sequence and reportedly pro­vide between1.7 and 2.5% additional luma BD-rate gain on the random-access coded sequences of the SDR common test conditions (CTC).However, the proposal does not affect the CTC since QPA is off by default.

Decision (SW): adopt

[JVET-M0511](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5322) Bug fix for rate control under all-intra [Y. Li, D. Liu, Z. Chen (USTC)] [late]

Presented Thu 8:30pm. Chaired by FJB

In VVC Common Test conditions, a TemporalSubsampleRatio value is set to be 8 under all intra configuration. This strategy is to simplify the testing procedure. For example, the sequence FoodMarket4 has totally 300 frames, when coding in all intra configuration, only 38 frames are extracted and coded. And the actual frame rate is the original sequence frame rate set in the config file divided by 8. However, as the the sequence original frame rate takes the value of 50 fps or 60 fps. Both two numbers are indivisible by 8. So how to represent the actual frame rate is an option. In VTM, the actual frame rate is implicitly regarded as a float number when printing out the statistic information of bit-rate. However, in case of rate control is enabled, the actual frame rate is explicitly set as a int number, by a successive rounding operation of the division. This inconsistency makes the target bits calculated by the bit-rate a bit different from the actually coded bits, from which the bit-rate is calculated. In this document, we propose to explicitly set the actual frame rate to be a float number in case of TemporalSubsampleRatio is enabled.

Simple bug fix.

Decision (SW): adopt.

[JVET-M0600](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5419) AHG10: Quality dependency factor based rate control for VVC [Z. Liu, Z. Chen, Y. Li (Wuhan Univ.), Y. Wu, S. Liu (Tencent)] [late]

Presented Thu 8:30pm. Chaired by FJB

This contribution presents some improvements based on the current rate control scheme proposed in JVET-K0390. With the proposed quality dependency factor based bit allocation algorithm, when using the anchor bit rate of VTM 3.0 as the target, there are 0.34%/3.45%/3.02% for Y/U/V coding efficiency improvements in random access (RA) configuration when compared with the rate control algorithm in JVET-K0390.

Decision (SW): adopt.

[JVET-M0840](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5671) Crosscheck of JVET-M0600 (AHG10: Quality dependency factor based rate control for VVC) [X. Wang (Kwai Inc.)] [late]

# Metrics and evaluation criteria (0)

Contributions in this category were discussed XXday X Jan. XXXX–XXXX (chaired by XXX).

# Withdrawn and missing contributions (23)

JVET-M0041 Withdrawn

JVET-M0074 Withdrawn

JVET-M0205 Withdrawn

JVET-M0325 Withdrawn

JVET-M0370 Withdrawn

JVET-M0414 Withdrawn

JVET-M0505 Withdrawn

JVET-M0565 Withdrawn

JVET-M0608 Withdrawn

JVET-M0607 Missing at end of meeting

JVET-M0609 Missing at end of meeting

JVET-M0642 Missing at end of meeting

JVET-M0695 Missing at end of meeting

JVET-M0784 Withdrawn

JVET-M0788 Withdrawn

JVET-M0824 Withdrawn

JVET-M0825 Withdrawn

JVET-M0841 Withdrawn

JVET-M0903 Missing at end of meeting

JVET-M0639 Missing at end of meeting

JVET-M0751 Missing at end of meeting

JVET-M0770 Missing at end of meeting

JVET-M0909 Withdrawn

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

## Plenary meeting Sunday 13 January 0900-1045, 1115-1400

Reports of the tracks were presented as follows:

Track A:

* The initial review had been completed for CEs assigned to Track A
* CE3-1.1.1 Intra sub-partitions coding mode (conceptually similar to prior “short-distance intra prediction”) with a different trade-off between gain and encoding run-time (at least 16 samples per partition; 2 or 4 partitions); this includes a reversal of coding order

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra Main 10 - Over VTM-3.0** | | | | | **Random Access Main 10 - Over VTM-3.0** | | | | |
| **Test #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| 1.1.1 | -0.59% | -0.44% | -0.47% | 112% | 103% | -0.29% | -0.31% | -0.15% | 102% | 103% |

In the plenary review, it was said that the reverse coding order part of this (which had not been discussed in the initial track review) was difficult to support in implementations, and asked whether the gain would be preserved if the reverse coding order aspect is removed. The proponent said the coding order reversal was a key part of the scheme. It was requested for a test to be performed of what the impact would be for not having that part of it. Revisit for that. [Resolved per notes elsewhere]

* CE3-2.4.c CCLM customization for chroma type (~6% for chroma for type 2 chroma content)

In the plenary review, it was reported that in a revision of M0142, test results had been provided for what would happen if type 2 processing were applied to type 0 content. The results indicated 0.17% degradation for luma, and ~2.1% for chroma. For class A1, the Campfire sequence had 0.83% degradation for luma, 11.36% for U, and 4.56% for V. It was noted that the subjective effect seemed likely to be greater. sps\_cclm\_collocated\_chroma\_flag = 0 would indicate type 0 processing.

* CE5-5.1.13\* +new init from 5.1.2 arithmetic coding engine

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Engine** | **AI** | **RA** | **LB** | **LP** | **AI** | **RA** | **LB** |
| 5.1.13\* +new init from 5.1.2 | -0.98% | -0.96% | -0.75% | -0.73% | 110/105 | 104/103 | 106/103 |

* CE6-1.1a/1.6a replacing 4-pt DST-7/DCT-8 by DST-4/DCT4

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **All Intra** | | | | | **Random Access** | | | | | **Low Delay B** | | | | |
| **Test #**  **Doc. #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CE6-1.1a/1.6a | -0.17% | -0.14% | -0.11% | 101% | 99% | -0.06% | 0.05% | 0.04% | 101% | 99% | 0.02% | 0.30% | 0.13% | 100% | 98% |

This has very small benefit, but no real impact on complexity. From a spec perspective, it is just a matter of the values of numbers in tables. It increases the number of types of transforms being used in the design and it was commented that having something different just for 4x4 seems conceptually inconsistent. It was noted that DST4 is part of DCT2. It was also noted that the impact on LB is negative. Some participants commented that the gain is too small to justify a change of the spec. The proponent commented that some gain was shown for LDB with inter-MTS on (0.07% with low-delay B). No gain was shown for low QP. It was agreed in the plenary *not* to adopt this change.

* CE6-2.3a DST-7/DCT-8 with dual implementation support (no coding efficiency impact)

In the AI configuration, this provides a reported 9% speed-up for the decoder, 4% for the encoder (as tested).

* CE6-3.1b Block shape adaptive transform selection, but with an extra high-level flag to use DCT2 always (benefit relative to an anchor that is not using MTS: AI 1.61%, RA 0.71%, LB 0.14%)

It was asked how much benefit this has relative to an encoder that, for rectangular blocks, chooses a fixed combination using the MTS syntax. The particular transform combination that this proposal uses for rectangular blocks has a DCT2 in one direct and a non-DCT2 transform in the other direction, which is not a combination supported in the MTS syntax, so that combination could not be selected in the suggested alternative low-complexity approach. It was commented that this may call into question the way MTS has been designed. Further study of these issues was encouraged.

* CE6-4.1a Sub-block transform with residual in only one sub-block (1-d split symmetric or 1/4; if symmetric, flag to indicate which half, otherwise use the smaller sub-block; transform type of residual TU inferred)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | **All Intra** | | | | | **Random Access** | | | | | **Low Delay B** | | | | |
| **Test #** | **Doc. #** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** | **Y** | **U** | **V** | **EncT** | **DecT** |
| CE6-4.1a | JVET-M0140 |  |  |  |  |  | -0.47% | -0.16% | 0.00% | 108% | 101% | -0.83% | -0.98% | -0.06% | 113% | 102% |

* CE7.4: In transform coefficient coding, the greater than 2 flag is moved to the first coding pass after the parity bit and the number of scans is reduced from 3 to 2 (very small coding efficiency improvement)
* In-loop “reshaping” seemed likely to be adopted.

Track B:

[Clean up the relationship between this section and the related notes elsewhere, avoiding duplication and adding cross-references]

As a general remark, it was established in Track B that “further study” means that technology should be studied in next CE on the subject area, whereas if such a remark is missing it implicitly means it shall not be studied in CE. If further study in an AHG is expected, that would be explicitly expressed.

Furthermore, the issue was raised that many (or most of) CE proposals came without specification text. It was agree that in future CEs, the text should be available by the time of the document deadline. Furthermore, CE contribution documents should be complete and not make it necessary to open old documents to understand the technology.

**CE2: Subblock motion compensation**

* CE 2.1: Affine motion compensation

Decision: Adopt JVET-M0246 (Test 2.1.2), extending AMVR to affine (but switching 1/16,1/4,full-pel). Use the AMVR high level flag for disabling both “normal” AMVR and “affine” AMVR. This provides 0.23% bit rate reduction.

In JVET plenary, it was agreed to use a separate flag, and disable this feature in CTC for LB, as the encoder runtime increase is not acceptable there.

* CE 2.2: Affine merge mode

Decision: Adopt JVET-M0381 Test 2.2.2a (reducing number of context coded bins in affine merge).

Track B initially suggested adoption of JVET-M0431, Affine merge with offset and block level signalling, and POC distamce based offset mirroring for bi pred. (test 2.2.4c on top of 2.2.4a) (using distance offsets 1/2, 1, 2, 4, and 8-pel as per table 2.1 of M0431). Add a high-level enabling flag.

In a follow-up discussion in the JVET plenary Sunday, it was agreed that the gain of 0.2% is too small to justify the additional syntax and increase in encoder runtime. No Adoption.

No action from following sub-CEs

* CE 2.3: Sub-block based merge mode
* CE 2.4: Complexity reduction
* CE 2.5: ATMVP and related topics

**CE4: Inter prediction and motion vector coding**

CE4.1: Merge mode simplification

Decision: Adopt JVET-M0281 (subtest 4.1.5a), Motion vector pruning: rounding before any MV pruning (unification for all DMVR cases)

CE4.2: Merge mode enhancement: No action

CE4.3: Parallel processing for merge mode: No action

CE4.4: Motion vector coding

Track B initially suggested adoption of JVET-M0403 modified MV coding (test 4.4.1a, 2 layer groups, where the first group is just the 0,0 MVD). This does not have compression benefit, but reduces the number of context coded bins from 4 to one, using joint coding of x/y. However, in the context of later discussion related to CE8, it was detected that this might have coding efficiency problems with CPR whichhad not been checked. Furthermore, it would be more difficult to check in the layer/index representation if the CPR range constraints are valid. It was also discussed in the JVET plenary that the benefit would be rather small.

Further, some revisits (depending on availability of additional data) for modifications of MMVD

CE4.5: Motion compensation constraints for complexity reduction: No action

**CE8: Screen content coding tools**

8.1 CPR related

It is suggested in CTC to enable CPR for class F. This would be realistic for the case where the encoder could know that it is screen content or natural content.

The methods of CE8.1.2 provide additional gain of >3% for class F, 8% for TGM class. These are re-using existing data from the previous CTU (assuming 2 or 4 buffers of size 64x64 each, depending on version). This is generally agreed to be practical and give good benefit. It could however be complicated to specify as an encoder/bitstream restriction that the limits of CPR vectors are valid. This still needs to be decided if it is mature for adoption.

Some methods provide additional gain (e.g. 0.4% class F, 0.9% for class TGM), but modify AMVP and merge list construction. Question is raised whether VVC would require to use exactly the same principle for CPR and normal MV coding. Probably this might be OK if it does not deviate too much, and does not require much additional processing. In HEVC SCC, it was required to have exactly the same process for CPR and MV coding, which may not be the case for VVC.

As a more fundamental aspect, it was discussed in the JVET plenary what general limitations we would impose on CPR design such as vector coding, and the status of CPR at large. In this context, it was agreed that it is desirable to define CPR as a separate mode that is also named differently, e.g. IBC. In terms of keeping the specification simple, it is nevertheless desirable to avoid arbitrary differences from building blocks of motion compensation, e.g. MV coding. IBC building blocks may deviate from those of motion comp if beneficial in terms of substantial improved compression or simplification. It is also notified that in the area of SCC material, “substantial” may mean several percents.

8.2: Palette related

Current VVC does not include palette mode, however a kind of “baseline” exists which is HEVC palette plus dual tree. This provides roughly 3%/7.5% gain over VVC+CPR for classes F/TGM. Results from CE also indicate that this gain goes to 2.5%/4.5% when combined with the improved CPR from 8.1.2. This may be even less when other aspects such as transform skip come into play. Such a relative low gain might not justify adding palette as an additional building block, and need for substantial amount of text in the spec.

As a more fundamental aspect, it was discussed what should be the design targets for palette. Improved compression performance may be more important than lowering complexity, to justify addition of such a mode.

In the JVET plenary, it was also discssed if it would be useful to include testing on 4:4:4 for screen content, renew the data set for screen content (no action was taken on this), and and generally provide mechanisms in VVC text and VTM to support 4:4:4 data.

8.3: Block-based DPCM

These approaches perform sample-wise DPCM as an additional concept that demonstrates some benefit for screen content types. The most viable approach (according to proponents) is 8.3.2 which can best be optimized in terms of throughput and also shows best compression. The gain over VTM+CPR is 3.7%/4.9% for classes F/TGM, and gain over VTM+CPR+PLT is 1.3%/1.4%, respectively. The encoder runtimes are significantly faster when those methods are used, as some early termination approach is employed (not searching other intra modes when the prediction works well).

The current method uses a maximum of 12 context coded bins per sample, which is much too large. No candidate for adoption, but further study in CE, with simplifications proposed in non-CE.

From CE8 related:

As mentioned above, the general consensus is that it is a right direction to signal CPR as a separate mode rather than using a special reference picture index.

JVET-M0483 comes with spec text (“method 3”), which however needs more careful inspection and modifications (also alignment with v9 of VVC draft 3).

JVET-M0464 Unified Transform Type Signalling and Residual Coding for Transform Skip

Signals TS before MTS (and therefore also enables it for blocks up to 32x32), but also changes the MTS binarization

* CTC: 0.01%, 103%, 101% (AI), -0.02%, 98%, 100% (RA), -0.07%, 102%, 102% (LB)
* Class F: -1.96%, 103%, 97% (AI), -2.14%, 98%, 100% (RA), -2.79%, 103%, 99% (LB)
* TGM: -8.04%, 106%, 88% (AI), -8.74%, 106%, 96% (RA), -9.21%, 112%, 97% (LB)

Additionally changing the residual coding for transform skip (first modification and second modification) results on average in (BD-rate Y, enc. time, dec.time):

* CTC: -0.16%, 103%, 100% (AI), -0.07%, 98%, 101% (RA), -0.07%, 101%, 101% (LB)
* Class F: -7.16%, 104%, 94% (AI), -5.76%, 98%, 100% (RA), -5.85%, 102%, 99% (LB)
* TGM: -21.03%, 108%, 82% (AI), -15.57%, 105%, 94% (RA), -14.01%, 111%, 95% (LB)

It is dicussed whether the aspect of signalling TS before MTS (and by that way enabling TS for block sizes up to 32x32, but also restricting it to luma) would rather be a straightforward syntax cleanup, which could be adopted at this meeting (but without modifying the MTS index binarization, which is discussed in CE6). However, results of TS modification are on top of VTC, would be desirable to see benefit for SC classes when CPR is on. This requires further consideration.

There are also other contributions JVET-M0072, M0269, M0279 and M0501 which also target TS.

**CE9: Decoder-side motion vector derivation**

CE9.1: BDOF design

Decision: Adopt JVET-M0487 (solution 9.1.1.b) which uses integer positions to generate the prediction samples in extended region, and uses 8-tap DCTIF filters to generate the prediction samples inside CU

No loss, but simplifies BDOF

CE9.2: DMVR design

Not decided yet, but good candidate for adoption: JVET-M0147 shows results without using refined MV for spatial MV prediction and deblocking: Overall -1.01%. This seems a reasonable approach avoiding all major dependency problems that were observed in DMVR before. This is however a variant for which cross-check still needs to be provided; specification text to be made available.

Generally, the investigation on DMVR has led to a point where it might be manageable implementation-wise (not low complex, but still giving around 1% gain)

A problem to be investigated: As currently tested, DMVR and BDOF could be applied sequentially, before finally motion comp and reconstruction can be done. JVET-M0223 considers this issue, still needs to be reviewed.

**CE10: Combined and multi-hypothesis prediction**

CE10.1:

10.1/10.2: Multi-hypothesis prediction: No action – gains are too low (and became lower than before, cut by half or even more) to justify additional complexity

In the context of reviewing 10.1.3.x proposals, which target simplifications of CIIP, the following aspects were identified:

- does it need a specific MPM derivation? If there was only one mode (as in 10.1.3a/d) it is not needed at all, and it is mentioned that there are proposals just suggesting fixed length coding

- CIIP does not have any serious latency issue. Therefore, simplifications that remove some processing steps that are otherwise used in intra prediction is not necessary.

- Sample-wise unequal weighting is not an implementation issue, whereas equal weighting would be preferrable, unless it costs compression performance or causes qualty problems.

Beyond the solutions tested in 10.1.3 more study is necessary on these aspects.

CE10.2: OBMC

Among the four proposals, version 10.2.1 seems the only one which is manageable from complexity perspective (but definitely adds some complexity). The test results are summarized as follows:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| # | Proposal | Config. |  |  | VTM |  |  |
|  |  |  | Y | U | V | EncT | DecT |
| CE10.2.1 | JVET-M0178 | RA | -0.27% | -0.58% | -0.62% | 104% | 103% |
|  |  | LB | -0.36% | -0.50% | -0.51% | 106% | 105% |

Track B initially suggested adoption of JVET-M0178.

During the JVET plenary, it was questioned whether such small gain was justifying the additional complexity. It is commented by several experts that OBMC may have positive impact on subjective quality. However, not such proof was available (and probably difficult to get). The decision was reverted.

CE on the previous investgated technologies 10.2.1…10.2.4 should be closed.

CE10.3: Multiple shape prediction partitions: No action

CE10.4: Diffusion filters for intra and inter prediction

new version uses FIR filters, applied on the prediction signal, switchable, not iterative. Two different 1D filters are 9-tap, symmetric, only 1 multiplication, otherwise shifts. One 2D filter is a 5-tap diamond shape, only shift/add operations. At the boundaries, one sample from neighbored reconstruction is used. The approach provides gains of 0.17%/0.42%/0.17%/0.87% for AI/RA/LB/LP. The method has been brought down to acceptable complexity impact for decoder, at some penalty in performance.

Two concerns are raised:

- As it needs to be run after the prediction signal is generated, it produces additional delay in the intra prediction loop.

- For inter blocks, it can be used for 128x128 CU, which would break concepts of 64x64VPDU.

It was requested to provide additional results without using the method in intra prediction (and the intra part of CIIP), and restrict the largest CU size to 64x64.

It is also reported that a late contribution (JVET-M0848) provides new results for the same method of 10.4.2 with some (small) encoder speedup and slightly increased performance.

Furthermore, it would be desirable to use only the prediction samples (no reconstructed samples from current picture). A version which did that was shown in the previous CE.

No decision yet on this.

CE10.5: Local illumination compensation

No action on current technologies, but continuation of CE to fulfill dependency/pipeline latency requirements.

**CE11: Deblocking**

Sub-tests

1) long-tap deblocking filters (11.1)

2) deblocking at 4x4 block boundaries (11.2).

The proposals were encoded according to two test conditions, which correspond to two anchors.

Anchor-1 is VTM-3.0 according to the CTC [1].

Anchor-2 is VTM-3.0 with ALF switched off (other conditions are the same as in Anchor 2).

CE11.1

Technology-wise understood and complexity-wise analysed, with some additional information on complexity requested.

It was pointed out that some of the proposals 11.1.1-5 did not consider that VTM3 now uses subblock boundary deblocking, whereas the decision of using long filters is based only on CU boundary properties. Therefore, it could happen that a long filter is applied first, and afterwards a subblock boundary within the CU is deblocked again. This would inhibit parallelism. This could be classified as a bug, which however in terms of subjective testing might not be too harmful.

CE11.2

VTM3 operates deblocking on an 8x8 grid. If a CU boundary is not on an 8x8 grid, it is not deblocked. If a CU is on an 8x8 grid, furthermore subblocks within that CU are deblocked (provided they are on the 8x8 grid as well). 4xN blocks are deblocked whenever they are coinciding with the 8x8 grid

11.2.1 deblocks on a 4x4 grid, where a boundary is deblocked with VTM filter when the next block or subblock is more than four samples apart, and with a weak and short filter if it is only samples apart.

11.2.2 uses an 8x8 grid and VTM deblocking filter but disables deblocking whenever the boundary would be only four samples apart.

Viewing in CE11 to assess necessity and benefit still to be done (being prepared).

General remarks on late delivery of text – text needs to be provided.

## Joint meeting Thursday 17 January 0900-0945

JVET with MPEG Systems and Requirements.

M46578 On the decoding interface for immersive media [Emmanuel Thomas (TNO) Rob Koenen (Tiledmedia) Thomas Stockhammer (Qualcomm)]

This has been called “Immersive media access and delivery” in some MPEG work, and there was an MPEG output document N 18071 at the October 2018 MPEG meeting.

This is for a scenario with additional processing that takes place after decoding; not a 1:1 mapping between output of decoder and display of the decoded video by the decoding system.

Example: 360° video tiled streaming using cubemap with each face of the cubemap segmented further into tiles. Using view-port-dependent streaming to only serve the tiles needed for viewing. Problems mentioned:

* Some systems having limits on the number of decoder instantiations.
* Need for systems coordination of timing.

An example approach is rewriting the bitstream to produce a “packed picture” that is decoded.

The proposed alternative is a decoder interface with a relatively large number of decoders – not necessarily a tile-level decoding interface from the video spec perspective – each decoder could be processing whole pictures from its perspective.

Another example: decoding of a background scene and a foreground object that are later composited by the system into a combined scene.

It is proposed to be able to mix profiles, colour formats, frame rates, picture resolutions, etc., using this tile-level interface.

Issues:

* Timing coordination (and ensuring decoding speed)
* Reference picture (or picture regions) management
* Other associated data used by a decoder
* Buffer flow characteristics

The subject was reported to be under consideration in MPEG Systems and Requirements, including as MPEG-I Architecture.

Simulcast “layers” as a way to do that. The proposal is a multi-stream model in which there are multiple independent (but synchronized) bitstreams.

It was commented that from an implementation perspective it is more complicated than a matter of memory capacities and resolution-dependent frame rates.

It was commented that this could involve a conformance point that constrains a combined set of decoders or decoder resources or bitstreams.

## Plenary meeting Thursday 17 January 0945-XXXX

Track A:

* Reference picture management in high-level syntax per JVET-M0128 (modified as noted)
* Small bug fixes from JVET-M0265
  + Fix the software to match the WD to remove clipping of luma MVs before deriving chroma MVs.
  + Adopt rounding away from zero for MV averages to remove inconsistency for similar averages: Offset = 1 << (F-1); M= S >= 0 ? (S + Offset) >> F: -((-S + Offset) >> F).

Flexible rectangular tile groups per JVET-M0853-v2 (constrained as noted), with software in JVET-M0445 and with loop\_filter\_across\_tile\_groups\_enabled\_flag from M0160 (confirmed in plenary)

* High-level syntax actions noted in discussion of JVET-M0816 BoG report.
* Simplification of division operation used in CCLM modelling from JVET-M0064.
* Simplifying PDPC linear interpolation to use nearest neighbour on secondary boundary for adjacent angular modes
* Bug fix in spec text related to CBF signalling identified in JVET-M0361.
* Reduce complexity of 32-length DST-7/DCT-8 using zero-out approach of JVET-M0297 Test 2.
* Enable transform skip up to 32x32 block size, with associated syntax approach in M0464 using tu\_mts\_idx (substantial gain for Class F / SCC).
* Bug fix for quantization group QP signalling to make the size consistent per M0113 & M0188 (text in M0113)
* Bug fix for transform skip quantization scaling factor for rectangular block shapes from M0119
* Bug fix for QP with parallel encoding – initialize QP from the bottom left CU of the above CTU row when decoding the first CU of a CTU on the left edge of a tile (text in a revision M0685).
* Non-normative (CTC): Enable transform skip for block sizes up to 32x32 in CTC (no effect on encoder runtime with M0464 encoder search modifications)
* Non-normative: Adopt M0864 memory bandwidth analysis method.

Reverse coding order part of CE3-1.1.1 intra sub-partitions coding mode and text  
 (Discussed in plenary Thu, 0.04% penalty for not doing reverse coding order, so adopt without that aspect; text available in revision of M0102.  
Further study suggest for limiting width to greater than or equal to 4.

Track A action item: Avoiding 32-point DST (with 64-length DCT2 on the other side) in CE6-4.1a [0.01% penalty reported in plenary Thu and avoiding all DST combined with 64-length DCT2 has 0.02% penalty, so no DST (including size 32, 16, 8 and 4) combined with 64-length DCT2]

Track A action item: CE12-2 in-loop remapping function (adoption action likely) – experiment results were discussed in a plenary Thu 17th; there was no significant penalty for the additional restrictions.  
The encoder algorithm was discussed. It was described in M0427.  
At a previous meeting, a curve-crossing problem had been observed and it had been suggested to do something about low-QP operation. There was said to be a very large amount of code in the encoder optimization, with resolution dependency and a smoothness measure and various thresholds and checks. Some of that code was reportedly related to a different variant (CE12-1) and can be removed. Some of it was for HDR, which was not measured in this test (but is also in-scope for VVC). It was discussed whether the code would be difficult to maintain and might have excessive tuning within the code. It was commented that the complexity had been reduced from previous versions. This has been tested in multiple rounds of CE and appears to provide significant gain if an adequate encoding method is use.  
  
Decision: Adopt (modified as noted).  
Further study is requested to study the encoder software and check the behaviour outside of the tested conditions.

Two other Track A action items were left open.

Track A also had recommended to discuss enabling CPR in CTC, at least for Class F.

Track B:

Reviewed all CE related BoGs (CEs 2, 4, 9, 10), CE8 & CE11 related had been reviewed in track

CE11 viewing ready, not reviewed, no conclusion yet

BoG on NN technology not reviewed yet

Various revisits still open pending on availability of more information. Most relevant are on CPR/IBC, deblocking, diffusion filters

New decisions:

- Adopt DMVR JVET-M0147 with SAD cost function&more details somewhere else (approx. 0.9%, 15% decoder runtime);

- Adopt combined merge list for adjacent 4x4 subblocks, JVET-M0170

- Adopt variant of CE4.4.3, symmetric MVD, and disable BDOF when used – gives 0.33% in RA, increases encoder time by 5%, JVET-M0444

- MMVD with switch (tile group header) to integer distance, benefical for screen content and UHD, JVET-M0255

- Adopt the approach of not signalling the triangular prediction mode flag in cases where the combination is not allowed (MMVD, CIIP) – various contributions on that, gives 0.07%

- Encoder RD optimization with deblocking knowledge shows 0.58%, 0.71% and 0.66% luma gain with similar encoding and decoding time, in AI, RA and LDB configuration respectively over VTM-3.0 anchor (SW adoption, not CTC unless HM would do the same). Could be used in some CEs as additional option, or mandatory.

- Hash-based motion search (JVET-M0253) – provides 7.8%/14.9% for classes F/TGM in RA, version that does not affect encoder run time for natural video, switches back to conventional ME – CTC or CTC only for SC. It was suggested in the plenary to go with the solution of enabling CPR via the SPS flag specifically for class F in CTC, and also manually enabling hash-based search for class F in CTC, but have the automatic switching as non-CTC in SW.

- Various adoptions of cleanups, harmonizations, simplifications with minor impact (look under BoG report)

* JVET-M0063 Non-CE9: An improvement of BDOF
  + Generalization of BDOF bit-depth restriction for internal bit-depths other than 10 bit.
  + No impact on CTC.
  + 8-bit coding scenario: -0.32/-0.32/-0.31% change in BD-rate (Y/CB/CR)
  + 12-bit coding scenario: -0.46/-0.03/0.08% change in BD-rate (Y/CB/CR)

From discussion in track B: A possible reason for this behaviour might be the wrong interpretation of the gradient in case of other bit depths than 10.

Question if the change would still be supporting the 16 bit SIMD design of software? Proponent confirms that this is the case, may need further checking by SW coordinators.

Decision (BF): Adopt JVET-M0063.

For plenary: What is general support of different bit depths in VVC? Might other tools that were added in recent meetings have similar problems. Definitely, bit depths up to 12 bits should be supported consistently, whereas it is likely that for higher bit depths some more precision might be required.

(also flexibility of spec in terms of other extensions, e.g. 4:4:4 would be desirable)

Action item for editors to identify potential actions.

Already detailed review and suggestions of technology to be investigated in ongoing CEs

Intent to start a new CE on NN technology, primary intent to get better understanding of adaptation mechanisms and complexity/compression performance impact, studying various methods that have been proposed with unified conditions and constraints.

Some aspects for ALF (particularly for saving line buffers) to be investigated in CE, also requires subjective inspection

Re-start CE investigations on post reconstruction filters (bilateral, Hadamard) but only using for inter. These give around 0.4% bit rate reduction for RA, which is still approximately the same as it was over VTM 2, so the gain seems to be additive with in VTM3. Both methods have quite some impact on complexity, where the new version of the bilateral filter is somewhat reduced relative to the previous version. Could however be conflicting with LIC in terms of latency, the latter is also under further investigation with additional constraints, these should be studied in combination.

## Closing plenary sessions

## Joint meetings

## BoGs (12)

[JVET-M0782](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5613) BoG report on tiles and WPP [Y.-K. Wang, M. M. Hannuksela]

This report was discussed in Track A Monday 14 January 1430-1630, 1830-2000 (chaired by GJS)

This contribution provides the report of the BoG on tiles and WPP.

The BoG recommended the following adoptions:

* Adopt JVET-M00853-v2 and add a NOTE like the following:

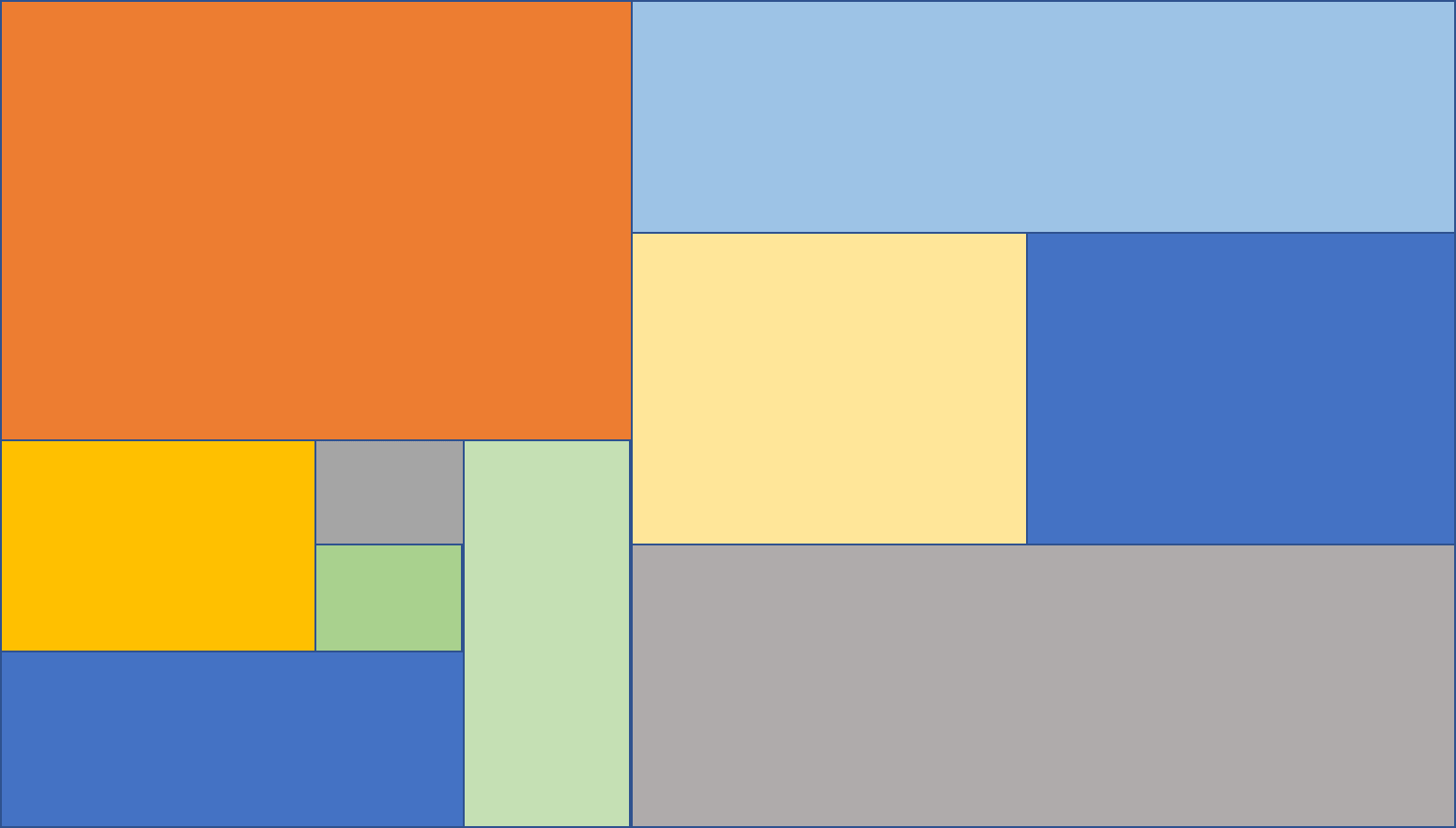
NOTE: When extracting an MCTS to form a conforming bitstream, active PPSs in the extracted sub-bitstream should have signalled\_tile\_group\_id\_flag equal to 1.

JVET-M00853-v2 adds the support of rectangular tile groups in addition to the existing raster scan ordered tile groups, and enables extraction of MCTSs without changing VLC NAL units.

Decision: Adopted, with constraints as follows:

* the tiles in a tile group need to be in raster-scan order.
* the tile groups need to be in increasing address order (see below: dark orange, then light blue, then pale yellow, then dark blue, then light orange, …)
* The tile group shapes shall be such that each tile, when decoded, shall have its entire left boundary and entire top boundary consisting of a picture boundary or previously decoded tile(s). In other words, the light yellow and light green tiles in the figure below are not allowed.

The following tile group picture was drawn for illustration and discussion purposes regarding the above constraints (an accidental *homage* to Piet Mondrian).



The BoG recommended to adopt the software implementation in JVET-M0445 into the VTM. Decision (SW): Adopted.

The software implementation in JVET-M0445 implements encoder motion constraints for MCTSs.

* Add loop\_filter\_across\_tile\_group\_enabled\_flag to the PPS, with syntax as proposed in M0160, and semantics as follows:

**loop\_filter\_across\_tile\_groups\_enabled\_flag** equal to 1 specifies that in-loop filtering operations may be performed across tile group boundaries in pictures referring to the PPS. loop\_filter\_across\_tile\_group\_enabled\_flag equal to 0 specifies that in-loop filtering operations are not performed across tile group boundaries in pictures referring to the PPS. The in-loop filtering operations include the deblocking filter, sample adaptive offset filter, and adaptive loop filter operations. When not present, the value of loop\_filter\_across\_tile\_groups\_enabled\_flag is inferred to be equal to 0.

Decision: Adopted (confirmed Thursday morning plenary).

* Add an AHG mandate on WPP into AHG 12. This was agreed in Track A.

The BoG and Track A agreed that it was desirable to have WPP support in VVC. The syntax, semantics, and decoding process for WPP are for further study.

The BoG recommended the following to be discussed:

* Whether to allow tiling with a tile width or tile height that is not a multiple of the CTU size

The late document M0875 was discussed – see notes on that contribution.

JVET-M0527 raised some concerns related to hardware implementation. And it was commented that in addition to the issues mentioned in JVET-M0527, this design also causes issues with line buffer ing, as well as in VDPU rate.

It was commented that a benefit of the design is enable turning off loop filtering across CMP faces. It was suggested that enabling loop filtering turning off within a tile would be a lighter solution than having this design. It was commented that there is ongoing CE on this.

Discussion resumed 1920 Monday 14 January (GJS).

It was thus suggested that these two topics should be discussed and decided together.

* The latest HEVC text specifies, as part of the semantics of an SEI message, the MCTS sub-bitstream extraction process and requires the extracted sub-bitstream to be conforming bitstream. For VVC, should we do more than this way of defining conformance for MCTSs? For example, should normative decoding process be specified for decoding of MCTSs instead of just specifying SEI messages for indication of the encoder motion constraints? There were several related proposals. For example, whether MCTS sequences are signalled in parameter sets or whether an MCTS sequence would have its own associated parameter sets. Whether to provide a level definition at the MCTS sequence level. Whether to define a normative decoder interface and conforming decoding behaviour for MCTS-specific decoding. Further study is highly encouraged.
* On whether to (allow) treat boundaries of MCTS / sub-picture sequences as picture boundaries (i.e., to do padding).

Allowing this is expected to help in coding efficiency. However, it would impose some burden for hardware implementations. Tests showing coding efficiency gain numbers and an analysis on hardware implementation complexity are needed for making a decision on this. Note that JVET-M0445 provides a software implementation that could be used as the basis and anchor for such coding efficiency comparison.

Interested parties were requested to work offline to prepare the test conditions. This effort was coordinated by M. Coban, the proposed test conditions were included in JVET-M0870.

It was thus suggested that JVET-M0870 be reviewed.

* Whether an interface for inputting/outputting reference pictures to/from the decoder could be acceptable in decoder implementation architectures.

This relates to allowing empty tiles and applying geometry padding to fill in the empty tiles in an external process as proposed in JVET-M0547. The contribution was also discussed in the 360o video BoG (see that BoG report).

It was commented that there could be other ways to indicate uncoded areas in the picture than using empty tiles.

The contribution would need an interface of outputting reference pictures (with uncoded areas) from the decoder to an external process and inputting reference pictures (with uncoded areas filled in by geometry padding) to the decoder from an external process. It was commented that this has some similarity to the external base layer concept of SHVC.

The bitstream would have some tiles that are not coded. The PPS could indicate where the uncoded areas are.

It was suggested that the tested benefit for cubeface geometry padding was about 2%. The subjective benefit may be greater. The anticipated benefit is rather limited, perhaps too small to be of interest by itself unless there is some other motivation for establishing a similar functionality. There have been other proposals for considering external management of reference picture memory and external control of the decoding process below the picture level. If there is a study of that broader potential need for a different system interface to the video decoding process, this could be part of it.

This was further discussed Wednesday 16 January 1445-1515 (GJS)

It was noted that the BoG had recommended considering M0375 after flexible tiling had been resolved.

This proposal would enable extraction of any row(s) or column(s) of tiles while still allowing the default layout to be indicated rather than requiring use of the explicit layout syntax.

It was commented that this may not fit the way some systems specs have a special mode for when the tiles are all the same size except at the picture edge. However, the proponent indicated that this scheme is better than that one for load balancing, and noted that HEVC was also using a default scheme that uses differing widths across the picture.

Another participant commented that this shifts larger tiles to the top-left and groups those together, which may not be optimal for load balancing when each thread is processing multiple tiles.

Further study was encouraged to determine whether the load balancing concern is valid and to consider the alternative of using equal tile sizes except at the right and bottom edges.

[JVET-M0816](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5647) BoG report on high level syntax [J. Boyce]

This BoG report was reviewed in Track A Sunday 13 January 1530 and further discussed Wednesday 16 January 1400 (GJS).

The BoG suggested discussion in the track or plenary regarding:

* Ask the following questions to ALF experts, for consideration when evaluating proposed solutions to improve coding efficiency of tile group headers:

1. How much bitrate do ALF parameters typically require? Perhaps typically about 200 bits (4 luma and 1 chroma), could be up to perhaps 2k bits
2. Do we expect that multiple pictures would use the same ALF parameters? 0.5% for RA in M0429. It was said to be undesirable to put them in the PPS since they change frequently.
3. What is the expected coding gain when ALF is used?
4. Does the ALF design support having different ALF parameters in different tile groups in the same picture? This hasn’t been tested but seems necessary to support having tiles that were generated by different encoders, and potentially desirable for other reasons as well.
5. If it is allowed to have different ALF parameters in different tile groups in the same picture, do we expect that they would frequently differ? See previous item. It hasn’t been tried.

The BoG met on 11 Jan 2019. The BoG also met on 12 Jan 2019, with the notes reflected in the -v2 version of the report document.

Decision: The following BoG recommendations were adopted in Track A:

* Replace the existing IRAP\_NUT with 3 new NAL unit types: IDR\_W\_RADL, IDR\_N\_LP, CRA\_NUT (from JVET-M0101).
* Add external means flag HandleCraAsCvsStartFlag, with similar text as in HEVC. Text provided in a v3 of JVET-M0101.
* Add a NUT value for step-wise temporal access STSA (from JVET-M0101).
* Add a NUT value for AUD (from JVET-M0101).
* Add sps\_max\_sub\_layers\_minus1 syntax element to SPS, and decoding process in 8.1.1, 8.1.2 and 8.1.3 of JVET-M0101.
* Add text of sections 7.4.2.4 to 7.4.2.4.5 on NAL unit order and AU boundary detection from JVET-M0101, which is primarily editorial, but has some technical aspects.
* Add profile\_tier\_level( ) syntax structure which includes sub-layer level idc (similar to HEVC but without sub-layer-specific profiles).
* Add general\_non\_packed\_constraint\_flag with semantics as in JVET-M0101 (rename the flag to display\_suitability\_flag? – that’s editorial).
* Add the temporal scalability sub-bitstream extraction process in JVET-M0101.
* Change the sps\_ref\_wraparound\_offset to sps\_ref\_wraparound\_offset\_minus1 and changing the units to be MinCbSizeY as in option 1, subject to review by the 360° BoG (minor cleanup).
* Add 7 new constraint flags corresponding to VVC WD 3 tools as described in M0451.
* Add reference picture signalling from M0128 (basic text version) – modified after Track A discussion as described in the notes for that document.

The BoG suggested discussion in the track or plenary regarding:

* Consider between adding 2 NUT values for RASL and RADL leading pictures or staying with no dedicated NUT values for leading pictures. Decision: Add RASL and RADL NUTs.

Further review of the BoG results was conducted Monday 14 January 1330 (GJS)

The BoG suggested discussion in the track or plenary regarding:

* Consider whether profile\_space should be included. This, and profile compatibility flags, were agreed to be for further study.
* Consider removing concept of I, P, and B slice (tile group) types, but to have flags to control the types of prediction (intra prediction, current picture referencing, inter prediction with one list or two lists), and whether this signaling should be for pictures or for tile groups. It was commented that it may not be necessary to indicate at the tile group level whether CPR is used in the tile or not. (Note that a tile has no header.) No need for action on this was identified.
* Consider whether an AHG should be formed to study solutions to problem of temporal judder when temporal scalability sub-bitstream extraction is used to lower frame rate. Consider whether this should have a normative impact or be supported in an SEI message (which could perhaps be done in JCT-VC for HEVC or AVC). Such a study could include consideration of pre- and post-processing. See JVET-M0579. It was suggested to establish an AHG on layered-coding scalability and resolution adaptation, and to include this topic in its mandates.
* Consider whether there is interest to normatively specify Gradual Decoder Refresh (GDR) operation, such that a conforming CVS can start with a GDR non-IRAP picture (as proposed in JVET-M0529). Further study in an AHG was encouraged. Some issues for study include how HRD interacts with the use case and whether it would be a burden to decoders to be required to support this capability.

The BoG also met 15 Jan from 1800 to 1930, with the notes reflected in the -v3 version of this document.

This was discussed in Track A Wednesday 16 January 1400-1445.

At the 15 January meeting, the BoG also recommended, and Track A agreed, to a further recommendation:

* Decision: Adopt an adaptation parameter set (APS) to carry ALF parameters. The tile group header contains an aps\_id which is conditionally present when ALF is enabled. The APS contains an aps\_id and the ALF parameters. A new NUT value is assigned for APS (from M0132). For the CTC, we will just use aps\_id = 0 and send the APS with each picture. For now, the range of APS ID values will be 0..31 and APSs can be shared across pictures (and can be different in different tile groups within a picture). The ID value should be fixed-length coded when present. ID values cannot be re-used with different content within the same picture.

Further study was encouraged for making use of shared values across pictures and different APSs in the same picture. Further study was also encouraged on whether to relax the constraint on re-using ID values.

[JVET-M0843](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5674) BoG report on CE4 related inter prediction and motion vector coding contributions [K. Zhang]

This report was reviewed in Track B Tue 15 Jan 1215-1330 and 1435-1800.

Five sessions were held, 1540 ~ 2020 on Jan. 11, 0900 ~ 1045 on Jan. 12, 1830 ~ 2000 on Jan. 12, 1945~2300 on Jan. 13, 2130~2230 on Jan. 14 for discussing 47 technical contributions in five categories:

1) Merge Modifications (19)

2) MMVD Modifications (12)

3) AMVP Modifications (7)

4) Weighted-Prediction Modifications (2)

5) Complexity Reduction (7)

Adoptions recommended by BoG:

**Normative changes**

Complexity Reduction

([JVET-M0193](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5000) CE4-related: Pairwise Average Candidate Reduction

0.01%/0.00% loss in RA/LB, reduce pairwise candidate from 6 to 1

([JVET-M0300](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5107) CE4-related: HMVP and parallel processing with tiles and tile groups

(this resets the history table at the beginning of each tile, however under the assumption that tile boundaries coincide with CTU boundaries which may not be the case with flexible tile concepts. It was suggested that proponents should communicate with tile experts and see whether there is a misaligment with concepts that will be put into VVC draft 4). It was later confirmed by the text editor that only a small (kind of editorial) change would be required. (might be that depending on further discussion on tile concepts, some more alignments may be necessary)

([JVET-M0117](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4922) CE4-related: On MVP candidate list generation for AMVP

0.01%/0.01%, pruning number 10->1, MV rounding 13->3

Bug Fix/Cleanup/Harmonization:

[JVET-M0436](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5245) AHG2: Regarding HMVP Table Size. Reducing number from 6 to 5. As the entry 6 is never used in the current spec, this is an editorial issue.

[JVET-M0264](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5071) Non-CE4: Harmonization between HMVP and GBi, such that the GBi weight is also stored in HMVP. Can be seen as a bug fix – gives very small improvement -0.01%/-0.01%.

[JVET-M0068](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4870) Non-CE4: MMVD scaling fix

-0.02%/0.00%, remove redundant scaling, makes it identical with regular MV scaling

[JVET-M0171](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4978) CE4-related: MMVD cleanups

-0.03%/0.02%, M0068+Forbid 4\*4 bi + align SW with WD

[JVET-M0111](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4916) AHG13: On bi-prediction with weighted averaging and weighted prediction

The same syntax design to support WP is also proposed in JVET-M0067

It is noted that inclusion of WP was decided by the 12th meeting, but not yet implemented in text (whereas the software had it). Furthermore, it had been decided to disallow combination of GBi and WP. This is implemented by disabling GBi signalling whenever WP is enabled for the current bi-predicted block.

[JVET-M0479](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5289) Non-CE4: On clipping of scaled motion vectors

0.00%/0.00%, always clip MVs to 18 bits

Coding Efficiency:

JVET-M0255 AHG11: MMVD without Fractional Distances for SCC

-1.58%/-2.74% in SCC (TGM class) tests with CPR off, -0.76%/-1.66% with CPR on, one slice level flag indicates whether distance is full-pel. It is further pointed out in the track B dicussion that it was demonstrated to provide benefit for UHD when such an option is available (see under CE 4.4.5). A version shall be used that just multiplies the current MVD distances by 4.

[JVET-M0444](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5253) CE4-related: Simplified symmetric MVD based on CE4.4.3

RA -0.33%, encoder is improved and BDOF is disabled on SMVD. 4.4.3 had a gain of 0.16%, but runtime increase of 5%, which is still the case here. By disabling BDOF, some run time is saved, but then more encoder checks are done on the SMVD, which is where the gain comes from.

[JVET-M0502](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5312) CE4-related: Improved context for prediction mode flag

-0.09%/-0.02%, add one context to code pred\_mode\_flag, no change of run time.

Decision: all the suggested adoptions are confirmed by trackB.  
(put the detail above under the corresponding contributions)

**Proposals suggested for study in upcoming CE:**

Merge-related

(Syntax modification

[JVET-M0069](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4871) Non-CE4: Syntax change of MMVD

-0.11% (102%, 100%)/-0.23% (102%, 100%). Decouple MMVD mode and merge mode

The proposal signals MMVD as separate mode, which appears desirable for a more clean design. There are also additional checks which might contribute to the improvement of compression, but also increase encoder runtime. Results should also be provided which implement the syntax change without increasing number of encoder RD checks.

[JVET-M0231](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5038) CE4-related: Regular merge flag coding

0.00% (100%, 96%)/-0.23% (102%, 92%). The codeword length for regular merge mode becomes the shortest one

[JVET-M0359](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5166) Non-CE4: Modification of merge data syntax

-0.06% (100%, 101%)/-0.17% (100%, 101%). MMVD flag is signaled when merge\_idx < 2

[JVET-M0369](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5176) CE4-related: Syntax changes of merge data

-0.07% (100%, 101%)/-0.14% (101%, 101%). Re-arrange order of the syntax elements for varieties of merge modes

It is noted in the track B discussion that the benefit of some of the last three methods is low, in particular if the separation of MMVD from merge (M0069) would be implemented. Therefore, also combination of M0069 and each of the other three should be tested.

(Merge list simplification

([JVET-M0405](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5213) CE4-related: Simplified merge candidate list for small blocks

0.09% (106%, 104%)/0.14% (108%, 107%). Only keep one spatial/temporal candidate without pruning when W\*H <=32.

(From track B dscussion: the loss does not justify the simplification, as there is no real complexity problem at the decoder. No value investigating this in CE)

[JVET-M0433](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5242) CE4-related: Constraint on GBi index inheritance in Merge Mode

0.03% (101%, 101%)/0.03% (102%, 102%). Remove GBI inheritance for affine merge and MMVD

(From track B discussion: The benefit is rather small, only 3 out of 84 bits are saved, and it generates a small loss. No value investigating this in CE).

(STMVP

[JVET-M0518](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5329) CE4-related: Supplemental results on STMVP design of CE4.2.3.a and combination with methods of JVET-M0126 (CE4.1.2.a) and JVET-M0127

-0.10% (100%, 100%)/0.06% (101%, 99%)

It is noted in the discussion in track B that this would definitely not be worthwhile to consider when there is still loss in LB. Might be better withdrawn when this is still the case by the time of submitting the CE software.

[JVET-M0713](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5536) CE4-related: simplification of CE4.2.2

-0.11% (100%, 100%)/0.00% (107%, 110%)

It is noted in the discussion in track B that CE4.2.2 disabled the method in LD, as it reportedly gave loss. Therefore, the same statement would apply as for JVET-M0518.

MMVD-related

(From track B discussion: This part should be combined with the Sub-CE on MMVD mode signalling above, in particular combination with JVET-M0069 should be investigated)

[JVET-M0206](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5013) CE4-related: MMVD improvements

-0.10% (102%, 103%)/0.01% (100%, 101%). Change the binarization method for MMVD distance index

[JVET-M0267](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5074) Non-CE4: Harmonization of MMVD and AMVR

-0.14% (100%, 100%)/0.00% (100%, 100%). Distance based on signaled AMVR

(From track B discussion: It should be clarified how this relates to the adoption of JVET-M0255, and different combinations tested (e.g. enabling only one, different ways of interpreting them together)

[JVET-M0307](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5114) CE4-related: Candidates optimization on MMVD

-0.08% (96%, 99%)/-0.02% (99%, 101%). Reduce distance candidates and introduce distance refinement

[JVET-M0308](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5115) Non-CE4: MMVD simplification

-0.01% (97%, 98%)/0.08% (100%, 99%). Remove MVD scaling in MMVD

(From track B: Not worthwhile, not in CE)

[JVET-M0314](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5121) CE4-related: MMVD improving with signaling distance table

-0.20% (103%, 97%)/0.02% (104%, 100%). Signaling the distance table in slice header

(From track B: Part of the gain comes from the encoder optimization “4.4.5\*”. So, the benefit of signalling as such seems to be low, in particular considering the increased encoder runtime. Not worthwhile, not in CE)

[JVET-M0315](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5122) Non-CE4: MMVD scaling simplification

Same as [JVET-M0308](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5115), and add one SPS flag

(From track B: Not worthwhile, not in CE)

[JVET-M0435](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5244) CE4-related: MMVD offset table signaling

-0,19% (100%, 99%)/0.01% (103%, 97%). Like [JVET-M0314](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5121) but with differential coding

(same comment applies as above for M0314)

TMVP Storage Reduction

(From dicussion in track B: This sub-CE is not needed, as JVET-M0512 solution was adopted.)

([JVET-M0230](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5037) CE4-related: Temporal MV buffer reduction

0.03% (100%, 100%)/0.09% (100%, 99%). Lower MV bits

This is a relevant reduction of buffer. However, it is suggested that instead of using scaling (1/16 to 1/4), simple clipping from 18 to 16 bits should be investigated as well.

In this context, it is mentioned in the track B discussion if it might be useful to define some restriction of MVs, just to prevent for some future application with extremely large picture sizes valid ranges might be exceeded.

([JVET-M0346](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5153) CE4-related: Non-square compression grid for temporal motion data storage

0.06% (100%, 100%)/ 0.23% (100%, 100%). MV stored in grid

([JVET-M0512](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5323) Non-CE4: On Temporal Motion Buffer Compression

0.00% (99%, 100%)/0.02% (100%, 102%). Remove POC storage and store MV in a converted way

From subsequent discussion in track B:

This approach stores the MV 8x8 grid in a floating point format, 6 bit mantissa (incl. sign) and 4 bit exponent. Has been cross-checked, text is available, provides significant reduction of MV memory. Comes with practically no loss and is well understood.

Decision: Adopt JVET-M0512 second aspect as described above.

The following open questions were reported by the BoG:

Depending on CE decision

*Pending on JVET-M0170 (which was adopted)*

([JVET-M0272](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5079) CE4-related: Restrictions on History-based Motion Vector Prediction

0.00% (101%, 101%)/0.02% (100%, 97%), disable HMVP table update for 4\*4 block; disable using virtual merge candidate for HMVP update; HMVP candidate is only pruned to the first two spatial/temporal merge candidates

(From Track B: first aspect not relevant after adoption of M0170. The third aspect was not relevant due to the CE4.1.1/2 decision which solved the problem of reducing pruning steps. The additional benefit of the second aspect standalone was not obvious).

([JVET-M0345](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5152) CE4-related: Remove redundancy between TMVP and ATMVP

-0.04% (100%, 100%)/0.00% (101%, 102%), Skip TMVP process in merge mode when CU size is equal to 8x8 or W=4 or H=4

(From follow-up in track B: The case of 4x4 is no longer relevant after adoption of M0170. This proposal would modify the merge list construction for cases for 8x8, 4xN, Nx4, N!=4. This introduces some irregularity, has only small gain, and is not critical case of processing. Put in CE.)

([JVET-M0473](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5283) Simplified HMVP

0.02% (100%, 101%)/0.02% (100%, 100%), HMVP table is updated at 16x16 grid, Remove reference checking in merge list pruning on HMVP candidates

(From follow-up in track B: Is not in a critical path and has slight loss – not worthwhile to consider)

([JVET-M0350](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5157) CE4-related: Quadtree-based Merge Estimation Region for VVC

0.49% (94%, 90%)/0.49% (93%, 91%)

In the follow-up discussion in track B, it is asked whether there would be much difference if it was implemented as encoder-only approach? It is probably good for some encoder runtime reduction, but has also quite some loss, so we would likely not adopt it or put it in CTC.

( (JVET-M0507 has two aspects, where the aspect of removing the clipping for the shared merge list might also be beneficial on top of JVET-M0170. It is reported to come at no coding loss. The proponents of M0507 discussed with proponents of M0170 that the check for one of the subbocks being outside of the picture could be removed, whereas another check whether the CU center is still inside needed to be added, to make it consistent with other boundary check conditions in VVC. Proponents of M0170 were to make an update on this aspect.

(*Related to JVET-M0281*

([JVET-M0081](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4884) Non-CE4: Simplification of AMVP list generation in AMVR

0.01% (101%, 99%)/0.03% (101%, 99%), Remove all intermediate rounding for AMVR mode, only keep the final rounding

From discussion in track B: The unification of where the rounding is done was achieved by adoption of JVET-M0281, no need to change that again.

(*Related to JVET-M0403*

[JVET-M0422](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5231) CE4-related: Simplified MVD coding

0.03% (100%, 100%)/0.02% (99%, 103%), bypass code coding abs\_mvd\_greater1\_flag

From discussion in track B: Saving context coded bins in MV coding does not have high relevance, as it hardly influences the worst case of CABAC throughput. Getting it at expense of loss is not desirable.

[JVET-M0406](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5214) CE2/4-related: Unified merge list size for block and sub-block merge modes

0.06% (101%, 101%)/ 0.10% (100%, 103%), unified merge list size = 5; -0.02% (101%, 101%)/ 0.00% (100%, 103%), merge list size = 6

[JVET-M0661](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5482) AHG-13: On Merge List Size

CTC use unified merge list size = 5.

From the discussion in track B: VVC3 has the choice of signalling merge list size. This is inherited from HEVC, where the design choice was to give an encoder the option to check less merge candidate, however it imposes some burden on decoders, as the parsing and signalling of merge candidates depends on the selected maximum number. It is discussed whether such encoder choice is still relevant for VVC.

It is further questioned whether unification of the merge list sizes is a relevant unification, as the merge list construction is different for regular blocks and subblocks, anyway. Even the coding and the context definitions are different.

No action on these two proposals.

**(**[JVET-M0330](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5137) CE4-related: Simplification of MMVD scheme

0.25% (93%, 98%)/0.07% (98%, 100%), reduce MMVD base candidates to 1; -0.06% (100%, 101%)/-0.12% (101%, 100%) reorder merge list construction based on block dimensions; Combined: 0.07% (94%, 98%)/-0.11% (98%, 100%)

From discussion in track B: Reduction of MMVD candidates gives loss and is mainly at benefit of encoder. At the last meeting, when MMVD was adopted, different numbers of candidates were considered and it was finally decided to use two, based performance/complexizy tradeoff. As the gap between using one and two candidates may have become smaller, it could be worthwhile to consider this aspect again on top of VTM4. Test this as part of the MMVD sub-CE, in combination with other proposals.

Changing the sequence of candidates based on block shape introduces some irregularity in merge list construction, which is not desirable (same proposal was investigated in earlier CE but not considered)

[JVET-M0857](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5688) BoG report on CE3-related intra prediction and mode coding [G. Van der Auwera]

(Track A Tuesday 1430-1630 GJS)

The BoG reviewed related input contributions to Core Experiment 3 on intra prediction and mode coding, and formulated recommendations for consideration by the track (A).

The CE3-related documents were categorized as follows:

* Cross-component prediction (14)
* Luma intra mode coding (8)
* Chroma intra mode coding (6)
* Interpolation of intra reference samples (4)
* PDPC-related (7)
* Various (7)

The BoG met on 11 Jan. 2019 from 9:00am–1:00pm, from 3pm–7pm, and on 12 Jan. 2019, from 9am–1:00pm, 3pm–6pm. [Incorporate into section 2]

The BoG made the following recommendations:

* Adoptions:
* JVET-M0064: simplification of the current VTM3 division operation used in CCLM modelling; VTM3 includes 2×512 tables (16 bit elements), which is reduced to one table with 16 entries (4 bit elements), and in addition the bit depth of the model slope parameter (alpha) is reduced from 15 bits to 5 bits. No significant coding efficiency impact was reported. Among proposals, this was the simplest approach. Decision: Adopted.
* JVET-M0095 (editorial): third proposed aspect harmonizes the filtering decision for the reference samples for all directional intra modes (VVC draft Table 8-4 value for nTbS=2 entry modified from 20 to 16). Editor action item: Agreed.
* JVET-M0238: linear interpolation that PDPC uses on the secondary boundary for adjacent angular modes is simplified to nearest neighbour. No significant coding efficiency impact was reported. This saves several calculations. Decision: Adopted.
* CE tests:
* Reducing the number of reference samples used to compute the cross-component linear model parameters: JVET-M0108, JVET-M0211, JVET-M0212, JVET-M0219, JVET-M0229, JVET-M0274
* Multi-model LM (MMLM): JVET-M0384 (determine the block size restriction that is required to improve the worst case of MMLM and evaluate different formulas to determine the knee-point for deriving the two models)
* Harmonization and simplification of MPM list construction: JVET-M0210, JVET-M0239, JVET-M0295 (method 1 + JVET-M0783 = JVET-M0815), JVET-M0494 (methods 2, 4, 5), JVET-M0528
  + Question: Does the scope of this test include MPM list construction of ISP, CIIP?
  + Remark: It is proposed to have one software codebase for testing the unification proposals and separate the unification tests from intra search RD effects. The planar prioritization aspects, context changes, can be tested on top of the unification tests in additional tests.
  + In Track A review Tuesday afternoon, it was suggested that the main goal should be to have a simplification and harmonization the different ways of how modes are selected. It was noted that CE10 also includes other proposals relating to MPM list construction (and for eliminating MPM usage) relating to CIIP and suggested that issues relating to MPM list construction be considered together in a CE.
  + Intra reference sample deblocking: JVET-M0138 (comparing the proposed method with strong intra smoothing method from HEVC in terms of complexity, artefact reduction) – this has a subjective effect – in Track A, it was agreed to plan to put this in the same CE as deblocking, since it has a similar need for subjective evaluation of deblocking artefacts.
* Open issues:
* BoG recommended to present and discuss following documents related to small block size restrictions in the category of complexity analysis and reduction (section 7): JVET-M0065, JVET-M0169.
* JVET-M0099: BoG recommended first considering other proposals are presented in the luma mode coding category. In Track A review it was agreed that such an optimization proposal should be deferred to later consideration once the elements of the design that are being optimized become more stable.
* BoG recommended considering the block size restrictions for PDPC preferably when additional hardware/software experts are present: JVET-M0045, JVET-M0122, JVET-M0238. In Track A review, this was suggested to also apply to JVET-M0814
* JVET-M0358: BoG recommended testing during the meeting, as additional result (AI and RA conditions; 1 tile/CTU configuration), the “AND condition” version of the reference sample availability conditions and report back during the current meeting. The proposal is that when the prediction mode is DC or planary only use PDPC when the above and left samples are both available. A test was run both for CTC and for a case with 1 CTU = 1 tile, so that there would be many instances of partial availability. The coding efficiency difference was very small, but was suggested to be larger subjectively. For the 1 CTU = 1 tile case, the coding efficiency benefit was 0.1%. This would introduce a different type of processing for planar and DC than what is currently included in the design – currently, these modes don’t need a “PDPC off” path. In CE10 there was a consideration of using planar mode without PDPC but this was not done. In the Track A discussion, it was agreed that the benefit seemed insufficient for adding an additional processing type that is otherwise not in the design (i.e., planar and DC without PDPC), since the 1 CTU = 1 tile case should have shown more benefit if there was a strong need. So no action was taken on this.

In the Track A review was a comment that there was an aspect of M0158 that might need further consideration. There are two 4-tap filters for angular mode intra prediction using the reference samples (one smoother one derived by training and the other a sharper filter derived as DCTIF which is the same filter used for MC interpolation of chroma). This contribution proposed using filter tap values derived from a formula instead of the values currently defined in a table. The contributor said there was a phase inconsistency in the current table of phases. An illustration of a case with a sine wave in the reference samples to show a periodic edge generation phenomenon with the current filters.

Another proposal M0095 would reduce the number of phases from 32 to 16 (for both luma and chroma). No action had been taken on that, as it was considered a minor issue at this stage.

No difference in coding efficiency was shown. This could be kept in mind in further work, but there didn’t seem to be a need to consider this change at this stage. It was remarked that these proposals may be logical, but we don’t need to consider such a small change before the design is more mature.

[JVET-M0858](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5689) BoG report on CE9 related decoder-side motion vector derivation contributions [S. Esenlik]

This report reviewed in Track B Wednesday 16 Jan 1115-1320 (JRO).

One session was held between 15:00 ~ 20:15 on January 12, 2019, for discussing 12 technical contributions in two categories, BDOF (7 contributions) and DMVR (5 contributions).

Recommended for adoption by BoG:

* JVET-M0063 Non-CE9: An improvement of BDOF
  + Generalization of BDOF bit-depth restriction for internal bit-depths other than 10 bit.
  + No impact on CTC.
  + 8-bit coding scenario: -0.32/-0.32/-0.31% change in BD-rate (Y/CB/CR)
  + 12-bit coding scenario: -0.46/-0.03/0.08% change in BD-rate (Y/CB/CR)

From discussion in track B: A possible reason for this behaviour might be the wrong interpretation of the gradient in case of other bit depths than 10.

Question if the change would still be supporting the 16 bit SIMD design of software? Proponent confirms that this is the case, may need further checking by SW coordinators.

Decision (BF): Adopt JVET-M0063.

Revisit (plenary): What is the general support of different bit depths in VVC? Might other tools that were added in recent meetings have similar problems. Definitely, bit depths up to 12 bits should be supported consistently, whereas it is likely that for higher bit depths some more precision might be required. [Editors to consider – needs to be resolved in further work]

Recommended CE tests, BDOF related:

* JVET-M0073 Non-CE9: On early termination for BIO
* JVET-M0249 Non-CE9: Modifications on Bi-Directional Optical Flow
* JVET-M0284 CE9-related: BDOF Modifications to Enable 64x64 VPDU
  + Regarding hardware implementation of BDOF, at least, there are two or three problems.
  + One is a buffering latency of SAD calculation for early termination before BDOF.
  + Second is huge number of memory access with large CU.
  + Third is memory access limitation to enable VPDU.
  + Creating a new CE to solve above problems.
  + None of the methods has significant impact on compression performance.

It was discussed in Track B if it might be better to remove early termination totally to simplify the design and solve the buffer latency problem, as this does not have impact on worst case complexity. Document JVET-M0890 reports that by removing the early termination, the result improves by 0.04%, but decoder runtime increases by 3%. This should be one of the comparison tests in the CE. Furthermore, the maximum size where early termination is used should be blocks of size 256 luma samples.

Recommended CE tests, DMVR related:

* JVET-M0077 CE9-related: Relaxation of block size restriction for DMVR
  + -0.81/-0.90/-1.00% change in BD-rate (Y/U/V) with 111/119% enc/dec time.

From the discussion in Track B: This is estimated to have up to 0.2% loss compared to the adopted version, and does not show decoding time decrease (even though it performs subsampling in SAD calculation). Not worthwhile to consider in CE.

* JVET-M0078 CE9-related: Combination of JVET-M0077 and CE9.2.5
  + Study early termination aspect of M0078 (which is also described in M0062) separately if MRSAD version of DMVR is included.

From discussion in Track B: Not necessary to study MRSAD, since SAD version of DMVR was adopted. There is another aspect that points out a similar problem as in JVET-M0063 where the early termination is dependent on bit depth and block size. As this would not affect CTC condition, there is no need to study in CE. Proponents are requested to study this aspect further with regard to the adopted version of DMVR.

* JVET-M0148 Non-CE9: Simplifications to DMVR search pattern and interpolation for refinement
  + First part proposes to replace 25 sample search space with 13 total points.
  + Approximately: 0.08/0.1/0.09% BD-rate change (Y/U/V) w.r.t. to the anchor that is used (CE9.2.1g).
  + Second part proposes simplification in complexity of bilinear interpolation of DMVR CE9.2.1g version
  + 0.04/0.03/0.04 BD-rate change (Y/U/V) w.r.t the anchor that is used (CE9.2.1g).

From discussion in Track B: Reduces decoder run time by approx. 1%. It also introduces some more specific processing at boundaries. Benefit not obvious, introduces some compression loss. Not worthwhile to consider.

* JVET-M0516 Non-CE9.2.1.e: Non-local-mean-based MRSAD and Row-subsampled Search Pattern for DMVR
  + Approach 1: proposes Non-local mean value calculation for MRSAD
    - 0.07% luma BD-rate increase with same enc/dec times. Benefit over SAD might be around 0.05% bit rate decrease.

From discussion in Track B: This still would require one more stage to first compute the mean before the SAD can be computed.

* + Approach 2: proposes 15 point row-subsampled search pattern.
    - 0.17% luma BD-rate increase with about 2% reduction in dec time

From discussion in track B: This amount of loss is not a good tradeoff versus the complexity benefit.

* + Approach 3: proposes to disable DMVR for 4xN and 8x8 DMVR.
    - 0.06% luma BD-rate increase with about 3% reduction in dec time
  + Approach 4: proposes to disable DMVR for 4xN and 8x8 DMVR, and also remove padding, such that in this combination the worst case memory BW would still be the same as 8x4 bi pred.
    - 0.04% luma BD-rate increase with about 3% reduction in dec time

It is further claimed that for the current DMVR (which only disables DMVR for Nx4 but not 4xN), the current worst case memory bandwidth may still be exceeded for certain memory access patterns.

Study the aspects 3 and 4 in CE, including an analysis of memory access bandwidth of current scheme and proposed schemes.

The following contributions were further discussed in track B:

* JVET-M0223 Non-CE9: Co-existence analysis for DMVR with BDOF

From discussion in Track B: In the current design, DMVR and BDOF may be processed sequentially (depending on condition that DMVR does not determine a modified MV, BDOF is computed). This contribution shows that parallel computation, and deciding by an additional cost criterion does not provide benefit. No action from the current approach, but it would be desirable to find another solution on the cascade operation.

* JVET-M0316 CE9-related: simplification of BDOF

From discussion in Track B: Benefit of re-defing the BDOF refinement such that no multiplications are necessary. Rate increase 0.15% for luma, 4-5% decoding time reduction.

As we don’t know the BDOF gain when operated together with DMVR, the loss may become lower in VTM4. Depending on the outcome, such a complexity reduction could be attractive. Study in CE.

* JVET-M0517 Non-CE9: Methods for BDOF complexity reduction

From discussion in Track B: Two aspects are considered a) subsampling in OF computation b) reduction of precision of multipliers. There is no noticeable change in decoder runtime, the benefit would be more relevant for hardware (in particular b). However, in BDOF the gradient computation is less of concern in terms of complexity. Overall benefit not clear – not relevant for CE.

[JVET-M0862](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5693) BoG report on CE2 related subblock motion compensation contributions [Y. He]

This report was reviewed in Track B Tue 15 Jan 1010-1215 (JRO).

Adoptions recommended by the BoG

**Normative changes**

[JVET-M0145](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4952): affine sub-block MV clipping, no loss, BF

JVET-M0192 (method 4)/JVET-M0462: sub-block MV derivation for chroma component, very small loss in chroma

JVET-M0166 (change 2)/JVET-M0228 (modification 1)/JVET-M0477(change 2), all proposing the same: remove MV comparison in constructed affine merge candidate derivation, 0.01% gain in RA, 0.01% loss in LB

JVET-M0273 (change 1)/JVET-M0240/JVET-M0116 (method 1)/JVET-M0338(method 1)/JVET-M0204(method 2): only using left neighbor for SbTMVP offset derivation. This has a loss of LDB 0.01%, none in RA

Decision: all the suggested adoptions are confirmed by trackB.  
(put the detail above under the corresponding contributions)

**Encoder optimization**

JVET-M0247: affine motion estimation for affine AMVR, gives 0.09% gain, but increases encoder runtime by 3% for RA.

JVET-M0839: increasing the number of RD checking for affine merge mode coding, 0.05% gain in RA, non runtime increase, somewhat larger gain in A1. However, cross-checkers report that the runtime is slightly increased by 1-2%.

It was discussed in track B whether these are giving enough benefit to justify. After all, the performance of the respective tools is somewhat increased, particular for large resolutions.

Decision: all the suggested adoptions are confirmed by trackB.  
(put the detail above under the corresponding contributions)

Technologies suggested for CE study:

*Affine motion compensation and affine MV coding:*

JVET-M0467: affine Symmetric MVD: Improves compression by 0.16% for RA with 8% runtime increase. It is pointed out in the discussion in track B that such a small gain for this amount of runtime increase would not justify adoption.

*Affine merge mode:*

JVET-M0166 (Change 1): selecting the MV having the reference index equal to 0 for both lists

(has 0.05% loss in LB, 0.01% in RA, but is asserted to be significant complexity reduction)

JVET-M0434: Applying constraint to constructed affine merge candidate

(0.02% gain in RA, no change in LB, complexity reduction)

*Worst case memory bandwidth reduction for sub-block modes:*

These methods resolve the problem that the worst case memory bandwidth of these modes is not worse than for other modes in HEVC. The comparison point should be using 4x8/8x4 also for bi pred or 4x4 uni in subblock (as per item 1), as this would be necessary without imposing such vector constraints. It is raised in the track B discussion that this CE should also investigate the visual quality impact.

(1) sub-block selection based on uni/bi-prediction: one test for JVET-M0226 (2.4.1.a, 2.4.1.b, 2.4.1.c), JVET-M0150 (2.4.3.b), JVET-M0472 (2.4.4.a, 2.4.4.b, 2.4.4.c and 2.4.4.d)

(2) sub-block MV clipping: JVET-M0309 (2.4.2), JVET-M0702

(3) adaptive sub-block size selection and interpolation filter switching: JVET-M0400, JVET-M0310

(4) padding based MC method for small block: JVET-M0248

(5) conformance method: a) JVET-M0049, b) JVET-M0049 plus the formula in JVET-M0400

(6) integer motion for small block bi-prediction MC (e.g. 4x8 and 8x4) : JVET-M0348

Local buffer storage reduction:

(JVET-M0110, JVET-M0168, JVET-M0270, JVET-M0266

It was agreed in track B that all the items above shall be investigated in CE.

Open issues from BoG, where additional presentation and discussion was performed in track B:

JVET-M0268, Non-CE2: Interweaved Prediction for Affine Motion Compensation

Additional results were presented in Track B which observe the VPDU constraint (denoted as test3/test4 in r2). These show that the gain of 0.27% (RA) is retained, while current worst case memory bandwidth of subblocks (relating to 4x4 bi) is not exceeded, also number of interpolations is not higher, and the additional superposition is cheap. However, as it is the goal to establish more restrictions on the memory bandwidth of affine subblocks (see notes on planned CE above) it would depend how the method of M0268 would perform in combination with those. Study this aspect in CE.

JVET-M0432, CE2-related: Combination of CE2.2.3.d and affine inheritance from motion data line buffer

In comparison to CE 2.2.3.d (which replaces the local buffer for CPMV by a history-based approach and this way reduces local memory storage), but came with 0.07%/0.09% loss for RA/LB, this method reinvokes the usage of the CPMV candidate from the normal MV buffer at upper CTU boundary. The loss compared to VTM3 is now 0.03%/0.07%. Further study in CE.

[JVET-M0343](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5150), Non-CE2: Simplified subblock motion derivation for SbTMVP

The complexity reduction is negligible, but small loss – no action.

M0311 was reviewed and agreed to become part of the CE on affine memory bandwidth reduction.

[JVET-M0873](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5704) BoG report on CE10 related combined and multi-hypothesis prediction contributions [C.-W. Hsu, M. Winken]

This report was reviewed in Track B Wed 16 Jan. 1500-1820 (JRO).

The CE10-related documents were categorized as follows:

* CIIP modifications (12)
* OBMC (2)
* TPM modifications (23)
* LIC (6)
* Other (1)

The BoG met on 13 Jan. 2019 from 6:00pm-10:30pm, 14 Jan. 2019 from 1:00pm-4:00pm, 14 Jan. 2019 from 7:30pm-11:00pm

Normative changes: recommendations of BoG:

Triangular mode:

1. Adopt syntax change of JVET-M0118: Same as in M0185, M0190, M207 (test 1), M0216 (the first aspect), M0234 (change corresponding to the result table 7 and 8), M0317 (section 2.2), M0328 (test E). This does not signal the triangular prediction mode flag in cases where the combination is not allowed (MMVD, CIIP). Approx. 0.07% rate reduction.
2. Adopt using only weight group (second weight as in JVET-M0328). The weighting is currently dependent on comparing MVs of the two partitions, loss approx. 0.01% for RA, 0.03% for LB, also simplifies the spec.
3. Adopt using only one context model for merge\_triangle\_flag (JVET-M0490). Increases bit rate approx. 0.01% for both RA and LDB, not a real severe complexity issue. Was discussed in track B, and concluded to better keep it unchanged for now.
4. Adopt signaling change of triangular merging candidate which does not need LUT (JVET-M0883). This is a combination from various proposals. Does not change merge list construction, simplifies the specification, and gives tiny gain (0.01% both for RA and LB)

Decision: Adopt recommendations 1, 2, 4 from list above

Recommendations for test in next CE:

TPM:

1. Merging candidate list construction (aspects from M0184, M0194, M0233, M0271, M0283, M0286, M0317, M0349, M0399):

* Re-use general merging candidate list construction as common part
* Study different variants thereof within CE

It was reported that this comes with basically no loss, and makes the merge not only unified but some proposals also simplify the merge list construction of triangular mode.

It was emphasized in track B that it might already be an advantage if the first part of merge list construction would be unified, and such a unification should not make the regular merge list derivation more complicated.

Further, the merge list construction of triangular merge list construction is not overly critical, so such modifications shall not penalize compression performance.

1. Signalling (has become obsolete by adoption 4. above, no CE necessary):

* All proposals use 3 syntax elements for the signaling (split direction and 2 merge indices)
* Study different variants thereof within CE

1. Study combination of triangular prediction and MMVD (within CE about motion vector coding)

(From discussion in track B: As the reported compression gain is probably lower due to the adoption 1. above, and the current approach has a high impact on encoder runtime, proponents should study the method and if a fast encoder method is available, make input to the next meeting, no CE)

TPM CE bullet point 1. To be included in CE4.

CIIP

1. Study intra/inter weights within a CE (M0096, M0454): M0454 reduces CIIP only with planar mode, and has identical weighting for the entire block (which is signalled). Compression gain 0.1%, but somewhat simplifies by removing unequal weighting, and also does not need special MPM list. M0096 has 0.1% gain in RA, 0.15% in LB, and uses equal for whole block, and only planar. The part of M0096 which applies PDPC after blending should be removed (see notes under M0492 below)
2. Study MPM generation for CIIP within a Sub-CE of CE3 (for comparison purposes this shall also include methods which don’t use MPM list for CIIP) (M0183, M0232, M0276, M0296): These target either simplification, harmonization, or improvement of the CIIP MPM coding. Gains are reported up to 0.02%. Compared to the benefits of CE CIIP 1., this does not seem to be competitive, as the latter does not need MPM signalling for CIIP at all, removes the non-uniform blending, and has slightly more gain. This sub-experiment would not have chances for adoption, unless something improves in these regards. Such ideas would better be brought as new proposals by next meeting.
3. Propagation of intra modes from CIIP blocks shall also be studied within CE (M0294): There is no compression benefit, and though some of the current design my appear “unlogical”, there is no problem with it, and propagating this information may even require more storage. If CE CIIP 1 would be successful, it is not needed anyway.

Establish bullet point 1. as CE.

LIC (M0088, M0115, M0182, M0224, M0450, M0500)

* Given that there will be further action on LIC, to minimize implementation complexity, LIC should be investigated having the following properties:
  + Usage of reconstructed intra coded, CIIP and IBC blocks, as this would have impact on complexity and parallel implementation pipelining (test with and without, and further study the impact)
  + Disabling LIC over CTU boundaries is not necessary
  + Disable for CIIP blocks
  + No temporal inheritance of LIC flag
  + No pruning based on LIC flag in merging candidate list generation
  + Disable LIC for all subblock modes
  + The VPDU issue should be solved (e.g., disabling for 128xN or by other method which avoids violating VPDU constraint).
  + Bi-Prediction issue should be solved (LIC should not have to be applied twice, i.e. for each L0/L1 as done in CE10.5.2). Possible solutions: Do it after bi-predictive combination or restrict LIC to uni-prediction.

Open issues discussed in Track B:

CIIP:

* JVET-M0492 ask hardware experts about their assessment.

From track B discussion: It was not possible to conclude. Some concern is raised that in hardware it may not allow re-using existing PDPC logic, as it is usually in pipelining connected to intra prediction, and here it would be connected to inter prediction. Furthermore, the proposal does not provide compression benefit (small loss in RA, small gain in LB, and the reduction of software runtime is low.

JVET-M0082 raises an issue on appearance of banding within CIIP blocks when horizontal/vertical modes are used, appearing at positions where the weight changes. Though it is not obvious that such such artifacts would still appear in a moving video, it is well noted but would be resolved in case when these modes would be removed, or the non-uniform weighting would disappear. However, there is no benefit (even some small compression loss) when only planar and DC are retained.

OBMC:

* JVET-M0357 has new OBMC results, which is however not directly related to current CE results. It uses uni prediction for the current block, and bi prediction (not integer accuracy, but sub-pel with shorter interpolation filter) for the overlap areas. It provides slightly higher gain than 10.2.2 (0.42% instead of 0.37%), but is not obvious to be less complex (though it has only 5 instead of 6 references to access, it employs additional interpolation, so in terms of signal processing there appears to be more complexity). Following the plenary decision, this is not enough evidence to re-open the OBMC CE.

Other:

* JVET-M0424 addresses an issue that might be with interpolation filtering (i.e., requiring 32 bit arithmetic in software)

This issue was discussed on the JVET reflector (see email of F. Bossen) – not clear if there is really a problem. Further evidence necessary before any action could be taken. Otherwise, gain by new filters is so small that it would not justify adoption by coding efficiency benefit. Needs further study but no topic for CE.

The current SIMD implementation is with 32 bit.

[JVET-M0874](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5705) BoG report on CE13 and CE13 related 360° video coding [J. Boyce]

(Track A 1600-1700 Thursday 17 January GJS)

The BoG met on 13 Jan 2019 from 1800 to 2030. The BoG met on 14 Jan 2019 from 1800 to 1900. The BoG met again on 16 Jan from 1700 to 1800.

The BoG recommended to adopt JVET-M0892 for disabling of in-loop filters (deblocking, SAO, and ALF) at vertical and horizontal boundaries signalled in the SPS at MinCbSizeY granularity.

It was noted that the change that was requested was not specific to 360° video.

It was noted that this proposed change is for entire columns / entire rows, not line segments that do not cut through the entire picture.

For a conventional cubemap, the filter would be disabled for one horizontal line in the middle of the picture.

It was discussed what sort of limit there would be for how many of these cuts would be allowed. One suggestion was a limit of 3 cuts in each direction.

The granularity was also discussed – whether it was really necessary to have 4x4 granularity.

It was discussed how this would be implemented in a real decoder. Checking a long list of positions would not be reasonable.

Due to a desire for further study of this before making a decision, no action was taken on this.

Further study was also recommended to consider more flexible in-loop filter disabling patterns, use cases, and HW implementation complexity.

The BoG endorsed the recommendation of HLS BoG to change the sps\_ref\_wraparound\_offset to sps\_ref\_wraparound\_offset\_minus1 and changing the units to be MinCbSizeY as in option 1.

The BoG recommended, and Track A endorsed, the following for the 360Lib software:

* Modify chroma sample location in blending process for PHEC (from JVET-M0368) – basically a bug fix
* Adopt Hemisphere CMP and Hemisphere EAC projection formats (from JVET-M0452)

Profiling was discussed. Thus far, we have not made any decisions that we believe would require having different profiles (perhaps bit depth, colour format, etc, but not coding features).

[JVET-M0877](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5708) BoG report on CE6 related transforms and transform signalling contributions [X. Zhao (Tencent]

(Reviewed in Track A Tuesday 15 January 1700 and Wednesday 16 January 1300-1400 (GJS)

The BoG met on Sunday January 13rd from 15:35 to 21:24 and Monday 14th from 20:30 to 22:10.

This BoG is mandated to review the CE6 related contributions of the 13th JVET meeting. Totally 25 contributions have been reviewed, which are categorized as follows,

1. Complexity reduction (14 proposals)
2. Transform skip (6 proposals)
3. Transform selection (2 proposals)
4. Others (5 proposals)

The following BOG recommendations were made:

* Recommended adoptions:
  + Context reduction (6 contexts reduced to 1 context) of MTS flag signaling (JVET-M0347). In Track A review, this was considered too small an optimization to bother with at this stage. It should be kept in mind when finalizing the spec as an opportunity for cleanup.
  + Bug-fix for mismatch between spec text and software related to CBF signaling (JVET-M0361, bug-fix on spec text). Decision: Agreed in Track A review – this was just an error in drafting the text.
* CE tests proposed by the BoG:
  + Modified transform selection
    - Transform selection for chroma components (JVET-M0480, JVET-M0501). We currently only have MTS for luma. In the Track A review, the potential improvement seemed small and this would involve needing to support multiple chroma transforms for chroma, so no CE was planned for this.
    - Transform selection to multi-hypothesis inter-intra mode (JVET-M0482). This proposal is to reduce the number of transform candidates in that mode. This would introduce a design inconsistency and has no benefit in coding efficiency. A non-normative approach has not yet been tried. No CE was planned for this.
    - Unification between MTS and transform skip (JVET-M0501). This reportedly shows 2.8% gain on Class F. In the Track A review, it was agreed to establish a CE for this.
* Open issues:
  + Complexity reduction of 32-length DST-7/DCT-8
    - With a zero-out approach (JVET-M0297, JVET-M0046) (0.1% penalty for AI, 0.04% for RA).
    - Using a two-stage transform scheme
    - Track A Decision: Adopt JVET-M0297 Test 2.
    - No CE.
  + MTS simplifications with modified transform candidates and signalling
    - BOG recommended revisiting in track A to discuss whether a CE study is to be set up for related contributions (JVET-M0304, JVET-M0366, JVET-M0340, JVET-M0202, JVET-M0464) – these propose ways to reduce the number of candidates. In Track A, it was agreed to study these in a CE:
      * M0304 eliminates DCT8 completely, so uses only DCT2 and DST7, and only sends one flag (reduces runtime, different tradeoffs with non-normative search changes)
      * M0366 uses a choice between 4 transform types instead of 5 (some gain and encoder time reduction)
      * M0340 (number of candidates depends and selection depends on block size and intra prediction mode, at most three transform pairs considered, a little loss and encoder runtime reduction) – Track A review indicated that this seems contrary to a Ljubljana action and complicates the scheme – not to be included in CE.
      * M0202 (tests removal of some candidates normatively or encoder-only).
    - The BoG recommended extending transform skip up to 16x16 (or 32x32?) only for class F (and TGM test sequences). The transform skip change is suggested in M0072 and M0464. A new version of M0464 was provided with experiment results combined with CPR, showing additional benefit. It proposes a truncated unary binarization for the signalling. M0072 does not change the signalling but has significant encoder runtime increase. M0464 has an encoder search modification that avoids encoder runtime increase. A cross-checker liked the encoder search modifications as a logical cleanup. Track A Decision: Adopt transform skip up to 32x32, with associated syntax approach in M0464 using tu\_mts\_idx. And enable TS for block sizes up to 32x32 in CTC for all test sequences. Further study was requested to identify potential runtime savings for disabling TS for some categories of test sequences.
    - The BoG recommended Track A to discuss further actions regarding the syntax changes of MTS signalling (JVET-M0464, JVET-M0201). This is resolved by action on M0464 noted above.
    - Software tool for computing transform throughput (JVET-M0540): The BoG recommended discussion in Track A to collect more opinions whether the proposed software tool can be used for evaluating the CE6 study. No action was taken on this, since there was not a plan for further CE work on transform speed-up approaches.

[JVET-M0891](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5722) BoG report on CE7 related quantization and coefficient coding contributions [(Y. Ye)]

This report was discussed in Track A Thursday 17 January 1700-1800 (GJS).

There were 13 technical contributions in the CE7 related category. These contributions are classified into the following three categories:

* Rice parameter related
* Complexity reduction and simplification
* Coding efficiency

The first BoG session was held 1900 – 2345 on Jan 14 2019 in Saba.

The second BoG session was held 1300 – 1400 on Jan 17 2019 in Saba.

Section 1 of this document summarizes the BoG’s recommendations. Section 2 of this document contains detailed notes on BoG discussion.

Recommended adoptions:

* JVET-M0470, CE7-related: Golomb-Rice/exponential Golomb coding for abs\_remainder and dec\_abs\_level syntax elements
  + In VTM 3.0, worst case is 33 bits for abs\_gt3\_level\_flag, and 35 bits for dec\_abs\_level for escape codes of coefficient levels, in comparison with is 32 bits for both syntax elements in HEVC.
  + Two aspects in this proposal: the first aspect uses a constant transition prefix code length of 6, and eliminates a LUT; the second aspect uses HEVC RExt extended precision scheme to limit worst case code length to 32 bits
  + Performance: 0.00%/0.01%/0.02% for AI/RA/LB
  + Proposed aspects seemed to be straightforward and aligned with HEVC. It also would solve a software issue that currently exists in VTM 3 that could cause decoder crash.

Decision (BF): Adopt JVET-M0470.

* JVET-M0251 (Non-CE7: Last position coding for large block-size transforms) and JVET-M0257 (CE7-related: coefficient scanning and last position coding for TUs of greater than 32 width or height)
  + Three contributions in this BoG tried to address the coefficient coding issues due to high frequency zeroing: M0250, M0251 (which is a superset of M0250), and M0257
  + Propose to scan only the portions of the transform blocks that have not been zeroed out
  + JVET-M0257 and JVET-M0251 are identical from spec text point of view, but simulation results are slightly different due to some difference in encoder implementation
  + M0257: 0.00% AI, -0.01% RA, -0.01% LB
  + M0251: 0.01% AI, 0.01% RA, full set of LB results not yet available at time of discussion
  + Recommend to adopt M0251/M0257. Use M0257’s encoder implementation (better performance and cleaner code)

Decision (BF): Adopt JVET-M0251/M0257 (software from M0257).

* JVET-M0305 CE7-related: Joint coding of chrominance residuals
  + The proposal adds a chroma residual coding mode where the Cr residual is not signaled, and is derived from the Cb residual by reversing the signs of the Cr residual.
  + The proposed method is applied to intra and inter coded blocks.
  + At the encoder side, the Cb and -Cr residuals are averaged together. In the proposed mode, that average residual is coded. RD decision is made to select between the conventional chroma coding method and this proposed method (in which case the average residual thus computed is coded). The mode flag is sent when the cbfs for both Cb and Cr are 1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Overall** | Y | U | V | Ave-UV |
| **AI** | -0.29% | -0.79% | -2.16% | -1.48% |
| **RA** | -0.19% | -1.44% | -2.00% | -1.72% |
| **LD-B** | -0.08% | -2.38% | -4.83% | -3.61% |
| **LD-P** | -0.11% | -2.46% | -5.08% | -3.77% |

* + This proposal achieves similar gains for all sequence classes and all coding configurations.
  + This method is simpler than an LM chroma mode that predicts Cr from Cb that was previously proposed, and achieves similar coding performance as that previous LM chroma mode. This complexity reduction of this proposed method compared to the previous LM chroma mode could be especially beneficial for the decoder.
  + It seems that such coding gain was usually not available from coefficient coding methods.
  + Low QP results (provided in a v3 of the contribution) were discussed at the second BoG session. The chroma gains are reported to be somewhat lower than those of CTC, but the gains in luma are similar to (AI case) or higher than (RA and LB cases) those of CTC.
  + In Track A, a participant commented wondered whether there could be subjective artefacts.
  + A participant asked how many blocks used this, and it was said that around half of the time that both channels had a residual, it would use this mode.
  + The proponent said it seems to also work for HDR.

Further study in a CE was planned for this.

BoG recommendations for CE testing:

* CE on coefficient coding (cleanup):
  + JVET-M0198, CE7-related: Unified Rice parameter derivation for coefficient level coding (some more computes but hardware friendly, removing one variation)
  + No test of this one (some loss): JVET-M0469, CE7-related: Unified Rice parameter derivation for coefficient coding
  + JVET-M0558: CE7-related: Template-based Rice parameter derivation (some more storage of reconstructed values and computes but hardware friendly, removing one variation)
  + No test of this one (don’t worry about number of contexts at this point): JVET-M0107: CE7-related: Reduced local neighbourhood usage for transform coefficients coding
  + No test of this one (don’t worry about number of contexts at this point): JVET-M0489: CE7-related: Reduced context models for transform coefficients coding
  + JVET-M0491: CE7-related: Reduced maximum number of context-coded bins for transform coefficient coding
* CE on screen content coding (coding efficiency)
  + JVET-M0278: Non-CE7: Residual rearrangement for transform skipped blocks
  + JVET-M0279: Non-CE7: Sign coding for transform skip

Regarding JVET-M0198, JVET-M0469 and JVET-M0558, during the BoG discussion, the pros and cons of the proposed approach vs the current design in VVC draft 3 were discussed. The approaches of JVET-M0198 and JVET-M0558 seemed to be more hardware friendly, whereas the current coefficient coding method in VVC draft 3 seemed to be more software implementation friendly.

This was discussed in Track A when determining which CEs to conduct.

[JVET-M0901](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5732) BoG report on quantization related contributions [Y. Ye]

This report was reviewed in Track A [get time from section2] (GJS).

There were 8 technical contributions in the quantization control category.

The first BoG session was held 2000–2330 on Jan 15 2019 in Olympia. The second BoG session was held 1300 – 1510 on Jan 16 2019 in Saba.

Section 1 of this document summarizes the BoG’s recommendations. Section 2 of this document contains detailed notes on BoG discussion.

* M0188 (On quantization parameter signalling considering CU area) and M0113 (CE7-related: Quantization Group size uniformity)
  + These two proposals solved the same problem of incoherent quantization group (QG) definition in VVC draft 3. They proposed essentially the same solution. However, the two proposals had different ways of expressing their solution in terms of WD text change. The proponents were encouraged to harmonize the suggested WD changes, and the final decision on WD text change should be deferred to the editors. The difference between the two descriptions is purely editorial. Further work was later done to harmonize the text. Decision: Adopt (text in M0113).
* JVET-M0119 CE7-related: Modified dequantization scaling
  + The second aspect of this proposal is recommended for adoption
  + In VVC draft 3, a scaling factor is applied when a transform block is of rectangular shape. This scaling factor should not be applied in the transform skip case. It was reported that in the reference software VTM-3.0, the scaling factor is applied in the inverse quantization stage and then removes it during the inverse transform stage. However, in VVC draft 3, the scaling factor is applied but not removed, which causes a mismatch between the software and the spec. This contribution removes the (unnecessary) application and removal of this scaling factor for transform skip blocks in the reference software, and proposes a WD change that fixes the mismatch between software and spec. Decision (bug fix): Adopt.

M0685

Prediction of QP value.

HEVC had a different QP prediction operation for when WPP is on and off. When WPP is off, any QP change will propagate to all subsequently coded blocks in the slice.

In the current draft the QP is predicted as the average of the QP above and to the left. If either of those is outside the CTU, the previous one in decoding order is used as the predictor.

This is a problem for parallel encoding, e.g., when encoding a CTU at the left edge, the QP predictor (which is from the right edge) may not be known.

M0685 proposed storing the QP values of the bottom of the above CTU and considering those “available”. If both are available, an average would be used; if one is unavailable, the other would be used.

In the discussion of the contribution, another method was discussed, which was to only have the QP of the above CTU available if the current CTU is the first CTU of the row.

It was noted that the QP values of the neighbour are already stored for deblocking purposes, so they could be used. Another person commented that the storage for deblocking may be in a different part of the decoding pipeline that would not be readily available.

The left-edge-only idea was suggested to potentially be beneficial for rate control in avoiding “dilution” of a delta QP.

Decision: Initialize QP from the bottom left CU of the above CTU row when decoding the first CU of a CTU on the left edge of a tile (text in a revision of M0685).

The BoG recommended study in an AHG on quantization control. This was agreed to be established.

It was noted that MTS affects the concept of quantization matrices.

[JVET-M0902](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5733) BoG report on contributions related to complexity analysis and reduction [B. Bross, A. Filippov]

Track A Wed 16 January 1515-1600 (GJS).

There are 10 technical contributions in the complexity related category. These contributions are classified into the following 4 categories:

* Small block size restrictions
* Complexity analysis
* Block size restrictions for PDPC
* Complexity reduction of motion compensation and MV coding

BoG sessions were held 19:15–21:00 on 01/15 in Coliseum. Section 1 of this document summarizes the BoG’s recommendations. Section 2 of this document contains detailed notes on BoG discussion.

The BoG recommended software adoption of M0864, which suggests an enhancement of the tool to measure the memory bandwidth in VTM.

Decision (SW): Adopt M0864 memory bandwidth analysis method.

The BoG recommended further discussion of the following:

**Summary of contributions on small block size restrictions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Contribution** | **Coding performance**  **(Y, Cb, Cr)** | **Disallowed block sizes** | **Intra prediction loop (throughput)** | **Other** |
| JVET-M0169  (can help both single and separate tree) | AI: 0.04%, 0.23%, 0.31%  RA: 0.07%, 0.43%, 0.54%  LD: 0.07%, 0.38%, 0.27% | None | 16 sample granularity | Unchanged |
| JVET-M0245  (does not help single tree case) | AI: 0.05%, 0.29%, 0.40%  RA: 0.02%, 0.39%, 0.42%  LD: -0.01%, 0.33%, 0.50% | Separate tree: Chroma 2x2/2x4/4x2 | 16 sample granularity in separate tree case, 4 otherwise. | Coef. Group:  2x8/8x2 for width/height 2 chroma blocks. |
| JVET-M0065  (not helpful for single tree case in hardware) | Option 1  AI: 0.00%, 0.04%, 0.03%  RA: 0.01%, 0.17%, 0.17%  LD: 0.03%, 0.27%, -0.11%  Option 2  AI: 0.03%, 0.26%, 0.38%  RA: 0.09%, 0.63%, 0.84%  LD: 0.00%, 0.24%, -0.43 | Option 1:  Separate tree: chroma 2x2  Option 2:  Separate tree:  chroma 2x2/2x4/4x2 | Option 1:  8 sample granularity in separate tree case, 4 otherwise.  Option 2:  16 sample granularity in separate tree case, 4 otherwise. | Option 1:  Single tree: 2x2 intra use DC only.  Option 2:  Single tree:  2x2/2x4/4x2 intra use DC only. |
| VTM-3.0 without small intra CU | AI: 0.03%, 0.26%, 0.38%  RA: 0.33%, 0.55%, 0.78%  LD: 0.21%, 0.17%, 0.60% | Chroma: 2x2,4x2,2x4  Luma: 4x4,4x8,8x4 | 16 sample granularity |  |

It was commented that it may be undesirable to depend on requiring decoders to be able to use parallel processing, since some (e.g., software) decoders may not be able to do that.

It was agreed to consider these approaches in CE3.

**Summary of contributions on block size restrictions for PDPC**

|  |  |  |  |
| --- | --- | --- | --- |
| **Contribution** | **Test #** | **Restriction** | **Compression performance (Y/U/V)** |
| JVET-M0045 |  | width + height <= 8 | AI: 0.05% / 0.02% / 0.03%  RA: 0.03% / 0.04% / 0.00% |
| JVET-M0122 | 1 | 1. width + height <= 8 2. width + height > 64 | AI: 0.03% / 0.04% / 0.02%  RA: 0.03% / 0.03% / 0.07% |
| 2 | 1. width + height <= 8 2. width + height > 64 (applicable only to blocks with worst-case intra-prediction modes) | AI: 0.03% / 0.03% / 0.04%  RA: 0.02% / 0.06% / 0.05% |
| 3 | 1. width + height <= 8 2. width + height > 64   Both restrictions are applied only to blocks with worst-case intra-prediction modes | AI: 0.01% / -0.03% / 0.00%  RA: 0.02% / 0.07% / 0.04% |
| 3a | width + height <= 8 (applied only to blocks with worst-case intra-prediction modes) | AI: 0.02% / -0.03% / -0.07%  RA: 0.01% / 0.01% / -0.04% |
| JVET-M0238 |  | width + height > 64 | AI: -0.01% / -0.02% / 0.02%  RA: 0.00% / 0.08% / 0.10% |
| JVET-M0814 | 1 | width \* height <= 16 | AI: 0.05% / 0.01% / 0.03%  RA: 0.03% / -0.05% / -0.01% |
| 2 | 1. width \* height <= 16 2. max(width, height) <=32 for luma, max(width, height) <=16 for chroma | AI: 0.06% / -0.08% / -0.08%  RA: 0.05% / -0.08% / -0.05% |
| 3 | width \* height <= 8 for chroma | AI: 0.00% / 0.03% / 0.02%  RA: 0.00% / 0.06% /0.02% |

It seemed unclear whether PDPC is particularly an issue for small blocks.

A participant indicated that it may be too early in the process, so that we shouldn’t optimize such aspects until the design is more stable.

No action was taken on these proposals, and no CE for them was planned.

M0248 was reviewed in the context of CE2 rather than in this BoG.

M0265 was not reviewed in the BoG. See notes for that.

[JVET-M0904](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=5735) BoG report on neural networks for video coding [Y. Li, S. Liu] [late]

This BoG report was presented in Track B on Thursday 17 Jan. 1500-XXXX.

This contribution provides the report of the BoG on neural networks (NN) for video coding, especially for neural network based loop filter. An information report (JVET-M0691) is discussed in this BoG, and then the CE plan.

The BoG recommends the following plan of CE:

* Divide the 6 NN based loop filter methods into two category and build two sub CE test.

SubCE1 is the test for sequence-adaptive (two-pass) method, SubCE2 is the test for sequence-independent (one-pass) method.

* Investigate the impact of NN filter position in the filter chain.

Due to there are many test cases, only choose some cases to test, as defined below.

* + For SubCE1:

anchor: DBF + SAO + ALF

case 1a : DBF + SAO + ALF + NN filter, which is the case currently subCE1 contributions used.

case 2a : NN filter. (optional test)

* + For SubCE2:

anchor: DBF + SAO + ALF

case 1a : DBF + NN filter + SAO + ALF, which is the case that most of the contributions used.

case 2a : NN filter. (optional test)

case 3a : NN filter + ALF. (optional test)

* Investigate the benefit of the CTU/block level NN filter adaptive on/off.

Define some cases to test. To test this part, other parts should be fixed, e.g., using case 1a as the position set and case 1c as the QP set.

case 1b: make the NN filter adaptive on/off at CTU level.

case 2b: always use NN filter in one slice. (optional test)

* Investigate the performance of the NN filter when the test QP is not the same as the training QP.

Define some cases to test. To test this part, one should fix using case 1a and case 1b.

Using CTC QP (22, 27, 32, 37) for training and get the NN parameter.

case 1c: based on the NN parameter, use CTC QP for testing

case 2c: based on the NN parameter, use CTC QP + 2 for testing (24, 29, 34, 39) (optional test)

case 3c: based on the NN parameter, use CTC QP - 2 for testing (20, 27, 30, 35) (optional test)

* More detailed assignment of CE can be seen in Table 3 and Table 4. Mandatory test and optional short test are marked in the Table 2.

The BoG recommended the following to be discussed.

* For subCE1, due to the online training, the NN parameter is not fixed. Thus, only providing the code in the inference stage is insufficient for others to use. (Although the parameter training/generation process is encoder only)

The proponent of Intel is willing to provide the training method, but not before the next meeting. The use of Tensorflow or other third-party framework in the common test conditions should be discuss in the track. Answer from the track: It may be useful if it is precisely described by which parameters a package like tensorflow is operated. An external optimization framework does not necessarily need to be part of our software package at the current stage of investigation.

* For subCE1, training process need GPU (using CPU is 10x slower), but the inference stage/second pass only use CPU. The training process is separated from the second pass. Currently, the encoding time listed in the table only includes the coding time for the second pass, and the training time is reported separately. Does it need to add the training time and second coding time for reporting? Or whether there is another better solution? Answer from the track: Should be reported, but not necessarily included in encoding time, as this would mix inhomogeneous computing platforms, and conclusions about the possibility of doing this in a meaningful amount of time can be drawn from separate reporting

An initial draft of a CE description was also included in the BoG report.

It was planned to run some of the tests only for short parts (e.g. one Intra refresh period). It is questioned whether this would give sufficient information, it is however planned to proceed like this for initial tests to identify configurations which then finally tested with entire sequence.

## List of actions taken affecting Draft 3 of VVC, VTM 3, 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.

# Project planning

## Core experiment planning

…

## Drafting of specification text, encoder algorithm descriptions, and software

The following agreement has been established: the editorial team has the discretion to not integrate recorded adoptions for which the available text is grossly inadequate (and cannot be fixed with a reasonable degree of effort), if such a situation hypothetically arises. In such an event, the text would record the intent expressed by the committee without including a full integration of the available inadequate text.

## Plans for improved efficiency and contribution consideration

The group considered it important to have the full design of proposals documented to enable proper study.

Adoptions need to be based on properly drafted working draft text (on normative elements) and HM encoder algorithm descriptions – relative to the existing drafts. Proposal contributions should also provide a software implementation (or at least such software should be made available for study and testing by other participants at the meeting, and software must be made available to cross-checkers in EEs).

Suggestions for future meetings included the following generally-supported principles:

* No review of normative contributions without draft specification text
* VTM algorithm description text is strongly encouraged for non-normative contributions
* Early upload deadline to enable substantial study prior to the meeting
* Using a clock timer to ensure efficient proposal presentations (5 min) and discussions

The document upload deadline for the next meeting was planned to be Wednesday 2 January 2019 (a little later than usual due to the proximity of the New Year holiday).

As general guidance, it was suggested to avoid usage of company names in document titles, software modules etc., and not to describe a technology by using a company name.

## General issues for experiments

It was emphasized during the opening plenary on January 9 that those rules which had been set up or refined during the 12th meeting should be observed. In particular, for some CEs, results were available late, and some changes in the experimental setup (particularly in CE4) were not discussed on the JVET reflector.

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). The CE coordinators are responsible for making sure tha the CE description is complete and correct and has adequate detail. Reflector discussions about CE description clarity and other aspects of CE plans are encouraged.
* A description of each experiment is to be approved at the meeting at which the experiment plan is established. This should include the issues that were raised by other experts when the tool was presented, e.g., interference with other tools, contribution of different elements that are part of a package, etc. The experiment description document should provide the names of individual people, not just company names.
* Software for tools investigated in a CE will be provided in one or more separate branches of the software repository. Each CE will have a “fork” of the software, and within the CE there may be multiple branches established by the CE coordinator. The software coordinator will help coordinate the creation of these forks and branches and their naming. All JVET members will have read access to the CE software branches (using shared read-only credentials; the method for members to obtain the credentials is TBA on the reflector).
* During the experiment, revisions of the experiment plans can be made, but not substantial changes to the proposed technology.
* The CE description must match the CE testing that is done. The CE description needs to be revised if there has been some change of plans.
* The CE summary report must describe any changes that were made in the process of finalizing the CE.
* By the next meeting it is expected that at least one independent cross-checker will report a detailed analysis of each proposed feature that has been tested and confirm that the implementation is correct. Commentary on the potential benefits and disadvantages of the proposed technology in cross-checking reports is highly encouraged. Having multiple cross-checking reports is also highly encouraged (especially if the cross-checking involves more than confirmation of correct test results). The reports of cross-checking activities may (and generally should) be integrated into the CE report rather than submitted as separate documents.

It is possible to define sub-experiments within particular CEs, for example designated as CEX.a, CEX.b, etc., where X is the basic CE number.

As a general rule, it was agreed that each CE should be run under the same testing conditions using one software codebase, which should be based on the group test model software codebase. An experiment is not to be established as a CE unless there is access given to the participants in (any part of) the CE to the software used to perform the experiments.

The general agreed common conditions for single-layer coding efficiency experiments are described in the output document JVET-J1010 (update).

Experiment descriptions should be written in a way such that it is understood as a JVET output document (written from an objective “third party perspective”, not a proponent perspective – e.g. not referring to methods as “improved”, “optimized”, etc.). The experiment descriptions should generally not express opinions or suggest conclusions – rather, they should just describe what technology will be tested, how it will be tested, who will participate, etc. Responsibilities for contributions to CE work should identify individuals in addition to company names.

CE descriptions contain a basic description of the technology under test, but should not contain excessively verbose descriptions of a technology (at least not unless the technology is not adequately documented elsewhere). Instead, the CE descriptions should refer to the relevant proposal contributions for any necessary further detail. However, the complete detail of what technology will be tested must be available – either in the CE description itself or in documents that are referenced in the CE description that are also available in the JVET document archive.

Any technology must have at least one cross-check partner to establish a 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 a CE.
* Participation in a CE is possible without a commitment of submitting an input document to the next meeting. Participation is requested by contacting the CE coordinator.
* All software, results, and documents produced in the CE should be announced and made available to JVET in a timely manner.
* All substantial communications about a CE, other than logistics arrangements, exchange of data, minor refinement of the test plans, and preparation of documents shall be conducted on the main JVET reflector. In the case that large amounts of data are to be distributed is recommended to send an announcement to the JVET reflector without attaching the materials, and send the materials to those who have requested it directly, or provide a link to it, or upload the data as an input contribution to the next meeting.

General timeline for CEs

T1= 3 weeks after the JVET meeting: To revise the CE description and refine questions to be answered. Questions should be discussed and agreed on JVET reflector. Any changes of planned tests after this time need to be announced and discussed on the JVET reflector.

T2 = Test model software release + 2 weeks or 4 March, whichever is earlier: Integration of all tools into a separate CE branch of the VTM is completed and announced to JVET reflector.

* Initial study by cross-checkers can begin.
* Proponents may continue to modify the software in this branch until T3
* 3rd parties are encouraged to study and make contributions to the next meeting with proposed changes

T3: 3 weeks before the next JVET meeting or T2 + 1 week, whichever is later: Any changes to the CE test branches of the software must be frozen, so the cross-checkers can know exactly what they are cross-checking. A software version tag should be created at this time and announced on the JVET reflector. The name of the cross-checkers and list of specific tests for each tool under study in the CE plan description by this time. Full test results must be provided at this time (at least for proposals targeting to be promoted to the draft standard at the next meeting).

CE reports may contain additional information about tests of straightforwared combinations of the identified technologies. Such supplemental testing needs to be clearly identified in the report if it was not part of the CE plan.

New branches may be created which combine two or more tools included in the CE document or the VTM (as applicable). [Search/remove obsolete references to BMS.]

It is not necessary to formally name cross-checkers in the initial version of the CE description document. To adopt a proposed feature at the next meeting, we would like see comprehensive cross-checking done, with analysis that the description matches the software, and recommendation of value of the tool given tradeoffs.

The establishment of a CE does not indicate that a proposed technology is mature for adoption or that the testing conducted in the CE is fully adequate for assessing the merits of the technology, and a favourable outcome of CE does not indicate a need for adoption of the technology.

Draft specification text shall be provided with CE input documents.

It was later discussed (Track B Wednesday 9 January afternoon) that it was unclear by which time such spec text should be available. It was mentioned that numerous (if not majority) of current CE contribution documents in the first uploaded version come without spec text. However, availability of spec text is important to have a detailed understanding of the technology and also to judge what its impact on the complexity of the spec will be. See notes of discussion of this in plenary.

Plans for the CEs to be conducted were established Thursday 18 January (GJS); CE plan documents were reviewed Friday 19 January (GJS & JRO).

Lists of participants in CE documents should be pruned to include only the active participants. Read access to software will be available to all members.

## Software development and anchor generation

The planned timeline for software releases was established as follows:

* VTM4.0 will be released by 2019-02-11. VTM4.1 with non-CTC adoptions will be released later. (If necessary, VTM4.0 may not include final tuning of context initialization values.)
* Further versions of VTM may be released for additional bug fixing, as appropriate.
* Preparation of the VTM software will include immediate removal of macros that were added in the previous meeting cycle. The software coordinator has the discretion to retain some such macros.
* Timeline of 360lib9.0: 1 week after the release of VTM4.0 (2019-02-18). 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. J. Sullivan (co-chairs) | N |
| **Draft text and test model algorithm description editing (AHG2)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Produce and finalize JVET-M1001 VVC text specification draft 4. * Produce and finalize JVET-M1002 VVC Test Model 4 (VTM 4) Algorithm and Encoder Description. * Gather and address comments for refinement of these documents. * Coordinate with test model software development AhG to address issues relating to mismatches between software and text. | B. Bross, J. Chen (co-chairs), J. Boyce, S. Kim, S. Liu, Y. Ye (vice-chairs) | N |
| **Test model software development (AHG3)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Coordinate development of test model (VTM) software and associated configuration files. * Produce documentation of software usage for distribution with the software. * Discuss and make recommendations on the software development process. * Propose improvements to the guideline document for developments of the test model software. * Perform tests of VTM 4 behaviour relative to HEVC and VTM 3 using the VTM common test conditions and the multi-resolution streaming test conditions described in JVET-M0466. * 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, A. Norkin, K. Sühring (co-chairs) | N |
| **Test material and visual assessment (AHG4)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Maintain the video sequence test material database for development of the VVC standard. * Identify and recommend appropriate test materials for use in the development of the VVC standard. * Identify missing types of video material, solicit contributions, collect, and make available a variety of video sequence test material. * Evaluate new test sequences, particularly including the material recently submitted by the Blender Foundation / Blender Animation Studio and Twitch. * Propose a new structure for the test sequence repository. * Facilitate availability of viewing equipment and facilities arrangements for the next meeting and pre-meeting testing as feasible. | T. Suzuki (chair), V. Baroncini, R. Chernyak, P. Hanhart, A. Norkin, J. Ye (vice-chairs) | N |
| **Memory bandwidth consumption of coding tools (AHG5)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Develop improved software tools for measuring both average and worst case of memory bandwidth, and provide information for usage of these tools. * Study cache configurations for measuring decoder memory bandwidth consumption. * Identify coding tools in CEs and VTM with significant memory bandwidth impact. * Study the impact of memory bandwidth on specific application cases. | R. Hashimoto (chair), T. Ikai, X. Li, D. Luo, H. Yang, M. Zhou (vice-chairs) | N |
| **360° video conversion software development (AHG6)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Prepare and deliver the 360Lib-9.0 software version and common test condition configuration files according to JVET-M1012. * Generate CTC (PHEC) anchors and PERP results for VTM according to JVET-M1012, and finalize the reporting template for the common test conditions. * Produce documentation of software usage for distribution with the software. | Y. He, K. Choi (co-chairs) | N |
| **Coding of HDR/WCG material (AHG7)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study and evaluate available HDR/WCG test content. * Study objective metrics for quality assessment of HDR/WCG material, including investigation of the correlation between subjective and objective results of the CfP responses. * Compare the performance of the VTM and HM for HDR/WCG content. * Prepare for expert viewing of HDR content at the 14th JVET meeting if feasible. * 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, cubeface layouts, spherical rotations | J. Boyce (chair), K. Choi, P. Hanhart, J.-L. Lin (vice-chairs) | N |
| **Neural networks in video coding (AHG9)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Investigate the benefit of using neural networks in video compression such as CNN loop filter, intra prediction, re-sampling in adaptive resolution coding, and encoder side partition mode decisions. * Investigate the complexity impact of using neural networks in video compression. * Investigate the complexity measurement of neural network coding tools. * Investigate the impact of training materials on the performance of neural network coding tools. * Investigate the impact of the training process on performance and complexity. | S. Liu (chair), B. Choi, K. Kawamura, Y. Li, L. Wang, P. Wu, H. Yang (vice-chairs) | N |
| **Encoding algorithm optimization (AHG10)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study the impact of using techniques such as GOP structures and perceptually optimized adaptive quantization for encoder optimization. * Study the impact of adaptive quantization on individual tools in the test model. * Study the quantization adaptation tool in the test model. * Investigate the feasibility of adding a CTC test category in which adaptive quantization is turned on. * Study quality metrics for measuring subjective quality using e.g. the CfP response MOS scores. * Investigate other methods of improving objective and/or subjective quality, including adaptive coding structures, adaptive quantization without signalling, and multi-pass encoding. * Study methods of rate control and their impact on performance, subjective and objective quality. | A. Duenas, A. Tourapis (co-chairs), C. Helmrich, S. Ikonin, A. Norkin, R. Sjöberg, T. Toma (vice-chairs) | N |
| **Screen content coding (AHG11)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Investigate coding tools targeted at screen content in terms of compression benefit and implementation complexity. * Identify test materials, discuss testing conditions for screen content coding, and propose associated updated common test conditions. * Study the impact of loop filters on screen content coding | S. Liu (chair), J. Boyce, A. Filippov, Y.-C. Sun, J. Xu, M. Zhou (vice-chairs) | N |
| **High-level parallelism and coded picture regions (AHG12)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study wavefront processing including the relationship with tiles and low delay characteristics. * Study flexible loop filter control and tile size restriction, including identifying implications on coding tools and implementation. * Study flexible tile partitioning (e.g. more flexible than HEVC and tile boundaries not spanning a full picture). * Study support of independently coded picture regions, including easy rewriting of such regions into a conforming sub-bitstream. * Prepare software and configurations for the test model to facilitate parallel processing tests. * Study the coding efficiency impact of parallel processing and coded picture regions. | S. Deshpande (chair), M. M. Hannuksela, R. Sjöberg, R. Skupin, W. Wan, Y.-K. Wang S. Wenger (vice-chairs) | N |
| **Tool reporting procedure (AHG13)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Prepare output document JVET-M1005, which describes the methodology of tool-off testing and a list of tools to be tested by identified testers. * Provide configurations files, bitstreams, and results of 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), Y.-W. Chen, R. Chernyak, K. Choi, R. Hashimoto, Y.**-**W. Huang, H. Jang, S. Liu, D. Luo (vice-chairs) | N |
| **Progressive intra refresh (AHG14)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Define relevant test conditions for the study of progressive intra refresh for random access without intra frames * Update the implementation of encoder-only intra refresh in the VTM model in the AHG14 fork of the software repository. * Evaluate different ways to produce intra refresh within VVC and characterize their coding efficiency impact, subjective quality, and delay characteristics, including encoder-only approaches and normative approaches * Consider the use of constrained intra prediction and tile-based approaches * Study recovery point handling, including practical implementation issues and perfect-versus-approximate decoded picture recovery. * Consider the potential need for starting a coded video sequence without an intra picture. | J.-M. Thiesse (chair), A. Duenas, K. Kazui, R. Sjöberg, 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) | N |
| **Implementation studies (AHG16)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study draft and proposed coding tools to identify implementation issues relating to decoder pipelines, decoder throughput, and other aspects of implementation difficulty. * Solicit hardware analysis of complex tools. * Particularly consider intra reconstruction throughput for small blocks. * Provide feedback on potential solutions to address identified issues. | M. Zhou (chair), J. An, E. Chai, K. Choi, S. Ethuraman, T. Hsieh, X. Xiu (vice-chairs) | N |
| **High-level syntax (AHG17)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study NAL unit header, sequence parameter set, picture parameter set, adaptation parameter set, and tile group header syntax designs * Study the proposed picture header designs and alternatives * Study reference picture buffering and list construction * Study random access signalling and random access approaches, including approaches with reference pictures provided by external means * Assist in software development and text drafting for the high-level syntax in the VVC design. | R. Sjöberg (chair), S. Deshpande, M. M. Hannuksela, R. Skupin, Y.-K. Wang, S. Wenger, H. Yu (vice-chairs) | N |
| **Quantization control (AHG18)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Identify methods for quantization step size control for luma and chroma, including spatially and frequency-adaptive approaches * Develop methods for evaluating quantization step size control operation * Study the impact of MTS transforms on quantization matrices and the need for default matrices * Study the interaction between in-loop “reshaping” and quantization step size control * Develop testing conditions for evaluating QP signalling improvements including rate control and perceptual optimization strategies as appropriate * Evaluate the performance of the current VVC QP design using the two adaptive quantization control techniques currently available in the VTM | R. Chernyak (chair), E. François, C. Helmrich, A. Segall (vice-chairs) | N |
| **Layered coding and resolution adaptivity (AHG19)**  ([jvet@lists.rwth-aachen.de](mailto:jvet@lists.rwth-aachen.de))   * Study adaptive-resolution coding approaches for real-time communication, adaptive streaming, and 360-degree viewport-dependent streaming, including filters for resampling, reference picture management, and related scope and signalling * Study approaches for temporal scalability to avoid temporal judder when temporal scalability sub-bitstream extraction is used for achieving lower frame rate, and consider whether this should have a normative impact. * Identify related test conditions, test sequences, and evaluation techniques (including subjective assessment techniques) * Study potential approaches for support of layered coding scalability including spatial, temporal, quality, and view scalability | S. Wenger and A. Segall (co-chairs), M. M. Hannuksela, Hendry, S. McCarthy, Y.-C. Sun (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-M1000](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5754) Meeting Report of the 13th JVET Meeting [G. J. Sullivan, J.-R. Ohm] (2019-03-08, near next meeting)

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

[JVET-M1001](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5755) Versatile Video Coding (Draft 4) [B. Bross, J. Chen, S. Liu] [WG 11 [N 18274](http://phenix.it-sudparis.eu/mpeg/doc_end_user/current_document.php?id=66428&id_meeting=177)] (2019-03-08)

(Initial version planned to be made available by 2019-02-01.)

See the list of elements under section **Error! Reference source not found.**, as agreed by the Wed. 18 October plenary.

[JVET-M1002](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5756) Algorithm description for Versatile Video Coding and Test Model 4 (VTM 4) [J. Chen, Y. Ye, S. Kim] [WG 11 [N 18725](http://phenix.it-sudparis.eu/mpeg/doc_end_user/current_document.php?id=66429&id_meeting=177)] (2019-03-08)

(Initial version planned to be made available by 2019-02-15.)

See the list of elements under section **Error! Reference source not found.**, as agreed by the Wed. 18 October plenary.

Remains valid – not updated: [JVET-K1003](http://phenix.it-sudparis.eu/jvet/doc_end_user/current_document.php?id=4112) Guidelines for VVC reference software development [K. Sühring] (2018-07-31)

New version?

[JVET-M1004](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5757) Algorithm descriptions of projection format conversion and video quality metrics in 360Lib (Version 9) [Y. Ye, J. Boyce] (2019-02-15)

Remains valid – not updated: [JVET-L1005](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4837) Methodology and reporting template for coding tool testing [W.-J. Chien and J. Boyce] (2018-10-26)

[JVET-M1006](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5758) Methodology and reporting template for neural network coding tool testing [Y. Li, S. Liu, K. Kawamura] (2019-02-01)

This output was produced to capture aspects specific to enable study of neural network techniques.

[JVET-M1010](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5759) JVET common test conditions and software reference configurations for SDR video [F. Bossen, J. Boyce, X. Li, V. Seregin, K. Sühring] (2019-02-01)

Update regarding CPR and hash search, used only for class F.

Enable inter MTS for lower-resoluitons? Perhaps in a CE, but not in CTC.

Remains valid – not updated: [JVET-L1011](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4832) JVET common test conditions and evaluation procedures for HDR/WCG video [A. Segall, E. François, S. Iwamura, D. Rusanovskyy] (2018-10-26)

Remains valid – not updated: [JVET-L1012](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=4840) JVET common test conditions and evaluation procedures for 360° video [P. Hanhart, J. Boyce, K. Choi, J.-L. Lin] (2018-10-26)

[JVET-M1021](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5751) Description of Core Experiment 1 (CE 1): Post-prediction and post-reconstruction filtering [J. Ström, S. Ikonen, V. Seregin]

[JVET-M1022](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5740) Description of Core Experiment 2 (CE2): Subblock motion compensation [C.-C. Chen, Y. He, H. Liu]

[JVET-M1023](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5746) Description of Core Experiment 3 (CE3): Intra prediction and mode coding [G. Van der Auwera, L. Li, A. Filippov]

[JVET-M1024](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5750) Description of Core Experiment 4 (CE4): Inter prediction and motion vector coding [H. Yang, G. Li, K. Zhang]

[JVET-M1025](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5744) Description of Core Experiment 5 (CE5): Adaptive loop filtering [C.-Y. Chen, V. Seregin]

[JVET-M1026](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5745) Description of Core Experiment 6 (CE6): Transforms and transform signalling [X. Zhao, H. E. Egilmez]

[JVET-M1027](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5741) Description of Core Experiment 7 (CE 7): Quantization and coefficient coding [H. Schwarz, M. Coban, C. Auyeung]

Coordination between CE7 and CE8 is desired for TS coefficient coding evaluation.

[JVET-M1028](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5748) Description of Core Experiment 8 (CE8): Screen Content Coding Tools [X. Xu, Y.-H. Chao, Y.-C. Sun, J. Xu]

Transform skip coefficient coding should be tested in CE8, and should be tested with low QP as well as with CTC.

Coordination between CE7 and CE8 is desired for TS coefficient coding evaluation.

[JVET-M1029](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5749) Description of Core Experiment 9 (CE9): Decoder Motion Vector Derivation [S. Esenlik, X. Xiu]

[JVET-M1030](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5742) Description of Core Experiment 10 (CE10): Combined inta/inter prediction [C.-W. Hsu, M. Winken]

[JVET-M1031](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5752) Description of Core Experiment 11 (CE11): Deblocking [A. Norkin, A. M. Kotra]

[JVET-M1032](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5743) Description of Core Experiment 12 (CE12): Tile set boundary motion compensation handling [Hendry, R. Skupin, W. Wan]

[JVET-M1033](http://phenix.int-evry.fr/jvet/doc_end_user/current_document.php?id=5753) Description of Core Experiment 13 (CE13): Neural-network based loop filtering [Y. Li, S. Liu, K. Kawamura]

Potentially obsolete notes: New CEs which may fill gaps in above numbering:

Adaptive loop filter [V. Seregin, …]

Post prediction/reconstruction filtering (include BF, HF, LIC, DIF) [J. Ström, S. Ikonin, …]

Neural network based loop filters [Y. Li, …]

# 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 of the first week and closing it on the Wednesday of the second week of the SG 16 meeting – a total of 9 meeting days), and
* Otherwise meeting under ISO/IEC JTC 1/SC 29/WG 11 auspices when it meets (starting meetings on the Wednesday prior to such meetings and closing it at lunchtime on the last day of the WG 11 meeting – a total of 9.5 meeting days).

In cases where an exceptionally 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:

* Tue. 19 – Wed. 27 March 2019, 14th meeting under ITU-T auspices in Geneva, CH.
* Wed. 3 – Fri. 12 July 2019, 15th meeting under WG 11 auspices in Gothenburg, SE.
* Tue. 1 – Wed. 9 October 2019, 16th meeting under ITU-T auspices in Geneva, CH.
* Wed. 8 – Fri. 17 January 2020, 17th meeting under WG 11 auspices in Brussels, BE.

The agreed document deadline for the 14th JVET meeting was planned to be Tuesday 12 March 2019. Plans for scheduling of agenda items within that meeting remained TBA.

WG 11, the local hosting organization Ecole Mohammadia d’Ingénieurs (EMI) – Mohammed V University, Rabat, Morocco, and Abdellatif Benjelloun Touimi were thanked for the excellent hosting and organization of the 13th meeting of the JVET.

GB Tech and Samsung were thanked for providing viewing equipment used during the 13th JVET meeting. Vittorio Baroncini was thanked for designing and coordinating the subjective test efforts related to CE11. The experts who helped in preparing and conducting the test, or participated in the role as test subjects, were also thanked.

Christian Tulvan was thanked for his continuous support and maintenance with regard to the JVET document repository.

The 13th JVET meeting was closed at approximately 1318 hours on Friday 18 January 2019.

# Annex A to JVET report: List of documents

# Annex B to JVET report: List of meeting participants

The participants of the thirteenth meeting of the JVET, according to a sign-in sheet circulated during the meeting sessions (approximately 267 people in total), were as follows:

1. Kiyofumi Abe (Panasonic)
2. Mariana Afonso (Univ. Bristol)
3. Jaehoon Ahn (LG Electronics)
4. Thomas Amestoy (Thales/IETR)
5. Kenneth Andersson (LM Ericsson)
6. Ichiro Ando (Nikon)
7. Saurav Bandyopadhyay (InterDigital Commun.)
8. Vittorio Baroncini (GBTech)
9. Max Blaeser (RWTH Aachen Univ.)
10. Saverio Blasi (BBC)
11. Frank Bossen (Sharp)
12. Jill Boyce (Intel)
13. Benjamin Bross (Fraunhofer HHI)
14. Sangguk Cha (Sejong Univ.)
15. Eric (Chi W.) Chai (Ubilinx)
16. Tsui-Shan Chang (Alibaba Cloud)
17. Ching-Yeh Chen (MediaTek)
18. Chun-Chi Chen (Qualcomm Tech.)
19. Jianle Chen (Huawei)
20. Jie Chen (Alibaba)
21. Lulin Chen (MediaTek)
22. Peisong Chen (Broadcom)
23. Xu Chen (Huawei Tech.)
24. Yi-Wen Chen (Kwai)
25. Roman Chernyak (Huawei)
26. Man-Shu Chiang (MediaTek)
27. Wei-Jung Chien (Qualcomm)
28. Byeongdoo Choi (Tencent)
29. Haechul Choi (Hanbat Nat. Univ.)
30. Jangwon Choi (LG Electronics)
31. Jiun Choi (LG Electronics)
32. Jungah Choi (LG Electronics)
33. Kiho Choi (Samsung Electronics)
34. Narae Choi (Samsung Electronics)
35. Woong Il Choi (Samsung)
36. Hsiao-Chiang Chuang (ByteDance)
37. Tzu-Der Chuang (MediaTek)
38. Takeshi Chujoh (Sharp)
39. Muhammed Coban (Qualcomm)
40. Philippe de Lagrange (Technicolor)
41. Santiago De Luxán (Fraunhofer HHI)
42. Zhipin Deng (Intel)
43. Sachin Deshpande (Sharp)
44. André Dias (BBC)
45. Jihoon Do (Korea Aerosp. Univ.)
46. Jie Dong (Qualcomm)
47. Andrew Dorrell (CiSRA / Canon)
48. Amith DSouza (Samsung)
49. Alberto Duenas (ARM)
50. Hilmi Egilmez (Qualcomm Tech.)
51. Semih Esenlik (Huawei)
52. Alexey Filippov (Huawei)
53. Edouard François (Technicolor)
54. Jiali Fu (Huawei)
55. Shigeru Fukushima (JVC Kenwood)
56. Arild Fuldseth (Cisco Systems Norway)
57. Alexandre Gabriel (TNO)
58. Raj Narayanan Gadde (Samsung)
59. Han Gao (Huawei)
60. Wen Gao (Harmonic)
61. Jaemin Ha (Sejong Univ.)
62. Haiyang Han (Sun Yat-Sen Univ.)
63. Heeji Han (Hanbat Nat. Univ.)
64. Soo-Chul Han (Vidyo)
65. Philippe Hanhart (InterDigital Commun.)
66. Miska Hannuksela (Nokia)
67. Ryoji Hashimoto (Renesas)
68. Yong He (InterDigital)
69. Yuwen He (InterDigital Commun.)
70. Christian Helmrich (Fraunhofer HHI)
71. Hendry (Huawei)
72. Félix Henry (Orange)
73. Tobias Hinz (Fraunhofer HHI)
74. Christopher Hollman (Ericsson)
75. Seungwook Hong (Huawei)
76. Yuling Hsiao (MediaTek)
77. Ted Hsieh (Qualcomm Tech.)
78. Chih-Wei Hsu (MediaTek)
79. Nan Hu (Qualcomm Tech.)
80. Yue Huang (Kwai)
81. Yu-Wen Huang (MediaTek)
82. Junyan Huo (Xidian Univ.)
83. Walt Husak (Dolby Labs)
84. Atsuro Ichigaya (NHK (Japan Broadcasting Corp.))
85. Tomohiro Ikai (Sharp)
86. Masaru Ikeda (Sony)
87. Sergey Ikonin (Huawei)
88. Shunsuke Iwamura (NHK (Japan Broadcasting Corp.))
89. Hyeongmoon Jang (LG Electronics)
90. Yongwook Jeon (LG Electronics)
91. Seungsoo Jeong (Samsung)
92. Wook Je Jeong (Chips & Media)
93. Hong-Jheng Jhu (Foxconn)
94. Jaehong Jung (Gaudi Audio Lab)
95. Jewon Kang (Ewha Univ.)
96. Alexander Karabutov (Huawei)
97. Kei Kawamura (KDDI)
98. Kimihiko Kazui (Fujitsu Labs)
99. Steve Keating (Sony)
100. Michel Kerdranvat (Technicolor)
101. Paul Keydel (Fraunhofer HHI)
102. Abdellatif Khindouf (Amevia)
103. Yoshitaka Kidani (KDDI)
104. Dae Yeon Kim (Chips & Media)
105. Dongcheol Kim (Wilus)
106. Hyung Kim (Cisco)
107. Jae-Gon Kim (Korea Aerosp. Univ.)
108. Jaeil Kim (SK Telecom)
109. Heiner Kirchhoffer (Fraunhofer HHI)
110. Geonjung Ko (Wilus)
111. Kyunghwan Ko (Pixtree)
112. Kenji Kondo (Sony)
113. Konstantinos Konstantinides (Dolby Labs)
114. Moonmo Koo (LG Electronics)
115. Anand Meher Kotra (Huawei)
116. Gosala Kulupana (BBC)
117. Jin Sam Kwak (Wilus)
118. Jani Lainema (Nokia)
119. Fabrice Le Léannec (Technicolor)
120. Julien Le Tanou (Ericsson Mediakind)
121. Brian Lee (Dolby Labs)
122. Bumshik Lee (Chosun Univ.)
123. Geonwon Lee (Sejong Univ.)
124. Hahyun Lee (Electronics and Telecom Research Institute (ETRI))
125. Jinho Lee (Electronics and Telecom Research Institute (ETRI))
126. Jong-Seok Lee (Kwangwoon Univ.)
127. Sangheon Lee (LG Electronics)
128. Sunyoung Lee (Pixtree)
129. Ya-Hsuan Lee (MediaTek)
130. Shawmin Lei (MediaTek)
131. Marc Leny (Ektacom)
132. Dotan Levi (Mellanox)
133. Guichun Li (Tencent)
134. Ling Li (LG Electronics)
135. Ming Li (ZTE)
136. Tim Li (Foxconn)
137. Xiang Li (Tencent)
138. Yiming Li (Wuhan Univ.)
139. Yue Li (Univ. Sci. & Tec. China)
140. Chongsoon Lim (Panasonic)
141. Jaehyun Lim (LG Electronics)
142. Ching-Chieh Lin (ITRI Intl.)
143. Jian-Liang Lin (MediaTek)
144. Po-Han Lin (Foxconn)
145. Yongbing Lin (Huawei Tech.)
146. Hongbin Liu (ByteDance)
147. Shan Liu (Tencent)
148. Yang Liu (Oppo)
149. Ye Liu (USTC)
150. Zizheng Liu (Wuhan Univ.)
151. Jian Lou (Alibaba)
152. Jiancong Luo (InterDigital Commun.)
153. Ajay Luthra (Picsel Labs)
154. Jackie Ma (Fraunhofer HHI)
155. Yan Zhuo Ma (Xidian Univ.)
156. Detlev Marpe (Fraunhofer HHI)
157. Ken McCann (Zetacast)
158. Sean McCarthy (Dolby)
159. Xuewei Meng (Peking Univ.)
160. Kiran Misra (Sharp)
161. Elie Mora (Ateme)
162. Karsten Müller (Fraunhofer HHI)
163. Junghak Nam (LG Electronics)
164. Shimpei Nemoto (NHK)
165. Tung Nguyen (Fraunhofer HHI)
166. Didier Nicholson (Vitec)
167. Jens-Rainer Ohm (RWTH Aachen Univ.)
168. Patrice Onno (Canon Research Centre France)
169. Seethal Paluri (LG Electronics)
170. Dohyeon Park (Korea Aerosp. Univ.)
171. Jae Yoon Park (SKKU Univ.)
172. Jun-Taek Park (Kwangwoon Univ.)
173. Min Woo Park (Samsung Electronics)
174. Minsoo Park (Samsung Electronics)
175. Naeri Park (LG Electronics)
176. Martin Pettersson (Ericsson)
177. Jonathan Pfaff (Fraunhofer HHI)
178. Pierrick Philippe (Orange Labs)
179. Yinji Piao (Samsung)
180. Chirag Pujara (Samsung)
181. Fabien Racapé (Technicolor)
182. Adarsh Krishnan Ramasubramonian (Qualcomm Tech.)
183. Jennifer Rasch (Fraunhofer HHI)
184. Justin Ridge (Nokia)
185. Antoine Robert (Technicolor)
186. Christopher Rosewarne (CiSRA / Canon)
187. Vasily Rufitskiy (Huawei)
188. Dmytro Rusanovskyy (Qualcomm)
189. Yago Sanchez De La Fuente (Fraunhofer HHI)
190. Eiichi Sasaki (Sharp)
191. Johannes Sauer (IENT)
192. Thomas Schierl (Fraunhofer HHI)
193. Heiko Schwarz (Fraunhofer HHI)
194. Andrew Segall (Sharp)
195. Vadim Seregin (Qualcomm)
196. Sriram Sethuraman (Ittiam)
197. Masato Shima (Canon)
198. Sandeep Shreshtha (Chosun Univ.)
199. Donggyu Sim (Kwangwoon Univ.)
200. Rickard Sjöberg (Ericsson)
201. Robert Skupin (Fraunhofer HHI)
202. Yumi Sohn (Samsung)
203. Timofey Solovyev (Huawei)
204. Juhyung Son (Wilus)
205. Sehoon Son (Pixtree)
206. Mukund Srinivasan (Ittiam)
207. Benno Stabernack (Fraunhofer HHI)
208. Jacob Ström (Ericsson)
209. Shiori Sugimoto (NTT)
210. Karsten Sühring (Fraunhofer HHI)
211. Gary Sullivan (Microsoft)
212. Yu-Chen Sun (Alibaba)
213. Yule Sun (Zhejiang Univ.)
214. Teruhiko Suzuki (Sony)
215. Yasser Syed (Comcast Cable)
216. Ali Tabatabai (Sony)
217. Masaya Takahashi (Nikon)
218. Anish Tamse (Samsung)
219. Jonathan Taquet (Canon Research)
220. Han Boon Teo (Panasonic)
221. Emmanuel Thomas (TNO)
222. Tadamasa Toma (Panasonic)
223. Pankaj Topiwala (FastVDO)
224. Alexandros Tourapis (Apple)
225. Chiaming Tsai (MediaTek)
226. Yi-Ting Tsai (ITRI)
227. Kyohei Unno (KDDI)
228. Geert Van der Auwera (Qualcomm)
229. Rahul Vanam (InterDigital Commun.)
230. Shuai Wan (NPU Univ.)
231. Wade Wan (Broadcom)
232. Biao Wang (Huawei)
233. Jiexi Wang (ByteDance)
234. Jun Wang (Sun Yat-Sen Univ.)
235. Li Wang (Hikvision)
236. Suhong Wang (Peking Univ.)
237. Xianglin Wang (Kwai)
238. Ye-Kui Wang (Huawei)
239. Stephan Wenger (Tencent)
240. Adam Wieckowski (Fraunhofer HHI)
241. Martin Winken (Fraunhofer HHI)
242. Dongjae Won (Sejong Univ.)
243. Ping Wu (ZTE UK)
244. Jizheng Xu (ByteDance)
245. Xiaozhong Xu (Tencent)
246. Jie Yao (Fujitsu R&D Center)
247. Yukinobu Yasugi (Sharp)
248. Chang-Hao Yau (ITRI international)
249. Yan Ye (Alibaba)
250. Peng Yin (Dolby Labs)
251. Sunmi Yoo (LG Electronics)
252. Yong-uk Yoon (Korea Aerosp. Univ.)
253. Hualong Yu (Zhejiang Univ.)
254. Lu Yu (Zhejiang Univ.)
255. Ruoyang Yu (Ericsson)
256. Yuangfang Yu (Oppo)
257. Kai Zhang (ByteDance)
258. Li Zhang (ByteDance)
259. Wenhao Zhang (Hulu)
260. Zhi Zhang (Ericsson)
261. Qun Zhao (Xiaomi)
262. Xin Zhao (Tencent)
263. Alexander Zheludkov (Beamr)
264. Xiaozhen Zheng (DJI)
265. Yunfei Zheng (Kwai)
266. Minhua Zhou (Broadcom)
267. Jian Qing Zhu (Fujitsu R&D Center)