Joint Collaborative Team on Video Coding (JCT-VC)
of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11
4th Meeting: Daegu, KR, 20-28 January, 2011

Document: JCTVC-D500

Title:	**Meeting report of the fourth meeting of the Joint Collaborative Team on Video Coding (JCT-VC), Daegu, KR, 20-28 January, 2011**
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Source: Chairs

Summary

The Joint Collaborative Team on Video Coding (JCT-VC) of ITU-T WP3/16 and ISO/IEC JTC 1/SC 29/WG 11 held its fourth meeting during 20-28 January, 2011 at the Hotel Inter-Burgo EXCO in Daegu, Republic of Korea. The JCT-VC meeting was held under the chairmanship of Dr. Gary Sullivan (Microsoft/USA) and Dr. Jens-Rainer Ohm (RWTH Aachen/Germany).

The JCT-VC meeting sessions began at approximately 9:10 a.m. on Thursday 20 January. Meeting sessions were held on all days (including weekend days) until the meeting was closed at approximately 1:55 p.m. on Friday 28 January~~October~~. Approximately 248 people attended the JCT-VC meeting, and more than 400 input documents were discussed. The meeting took place in a co-located fashion with a meeting of ISO/IEC JTC 1/SC 29/WG 11 (MPEG) – one of the two parent bodies of the JCT-VC. The subject matter of the JCT-VC meeting activities consisted of work on the new next-generation video coding standardization project now referred to as High Efficiency Video Coding (HEVC).

The primary goals of the meeting were to review the work that was performed in the interim period since the third JCT-VC meeting in implementing the HEVC Test Model (HM), review results from Core Experiments (CE), review technical input documents, further develop Working Draft and HEVC Test Model (HM), and plan a new set of Core Experiments (CEs) for further investigation of proposed technology.

The JCT-VC produced three particularly important output documents from the meeting: the HEVC Test Model 2 (HM2), the HEVC specification Working Draft 2 (WD2), and a document specifying common conditions and software reference configurations for HEVC coding experiments. Moreover, 14 documents describing the planning of CEs were drafted.

For the organization and planning of its future work, the JCT-VC established eighteen "Ad Hoc Groups" (AHGs) to progress the work on particular subject areas. The next JCT-VC meeting will be held during during 16-23 March 2011 in Geneva, Switzerland under the auspices of ITU-T Q6/16. Subsequent meetings are planned to be held during 14-22 July 2011 under WG 11 auspices in Torino, IT, 22-30 November 2011 under ITU-T auspices in Geneva, CH, and 1-10 February 2012 under WG 11 auspices in San José, USA.

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

The reflector to be used for discussions by the JCT-VC and all of its AHGs is the JCT-VC reflector: jct-vc@lists.rwth-aachen.de. For subscription to this list, see http://mailman.rwth-aachen.de/mailman/listinfo/jct-vc.

1 Administrative topics

1.1 Organization

The ITU-T/ISO/IEC Joint Collaborative Team on Video Coding (JCT-VC) 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 JCT-VC are ITU-T WP3/16 and ISO/IEC JTC 1/SC 29/WG 11.

The Joint Collaborative Team on Video Coding (JCT-VC) of ITU-T WP3/16 and ISO/IEC JTC 1/SC 29/WG 11 held its fourth meeting during 20-28 January, 2011 at the Hotel Inter-Burgo EXCO, in Daegu, Republic of Korea. The JCT-VC meeting was held under the chairmanship of Dr. Gary Sullivan (Microsoft/USA) and Dr. Jens-Rainer Ohm (RWTH Aachen/Germany).

1.2 Meeting logistics

The JCT-VC meeting sessions began at approximately 9:10 a.m. on Thursday 20 January, 2011. Meeting sessions were held on all days (including weekend days) until the meeting was closed at approximately 1:55 p.m. on Friday 28 January. Approximately 248 people attended the JCT-VC meeting, and more than 400 input documents were discussed. The meeting took place in a co-located fashion with a meeting of ISO/IEC JTC 1/SC 29/WG 11 (MPEG) – one of the two parent bodies of the JCT-VC. The subject matter of the JCT-VC meeting activities consisted of work on the new next-generation video coding standardization project now referred to as High Efficiency Video Coding (HEVC).

Information regarding logistics arrangements for the meeting had been provided at http://mpeg95.org.

1.3 Primary goals

The primary goals of the meeting were to review the work that was performed in the interim period since the third JCT-VC meeting in producing the HEVC Test Model (HM) software and first Working Draft, review results from Core Experiments (CEs), review technical input documents, and establish second versions of the Working Draft and HEVC Test Model (HM).

1.4 Documents and document handling considerations

1.4.1 General

The documents of the JCT-VC meeting are listed in Annex A of this report. The documents can be found at http://phenix.it-sudparis.eu/jct/.

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

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 (rather than as contribution registration and upload times) follow the local time at the meeting facility.

There were some difficulties with the web site's handling of the document registration for contribution JCTVC-D061. The web site initially placed it in the Guangzhou meeting directory rather than the Daegu directory, which may have caused some confusion over how to find it. This also occurred for JCTVC-

D317, but in that case the situation was rapidly corrected by re-registering the contribution as JCTVC-D327 and withdrawing the prior registration.

1.4.2 Late and incomplete document considerations

The formal deadline for registering and uploading non-administrative contributions had been announced as Saturday, January 15, 2011.

Non-administrative documents uploaded after 9:00 a.m. in Paris/Geneva time Monday January 17 were considered late.

Most documents in this category were CE reports or cross-verification reports, which are less problematic than late proposals for new action (and especially for new normative standardization action).

Late technical proposals that requested action included the following documents:

- JCTVC-D071 (a technical proposal)
- JCTVC-D241 (a technical proposal)
- JCTVC-D246 (a technical proposal)
- JCTVC-D253 (a technical proposal)
- JCTVC-D254 (a technical proposal)
- JCTVC-D342 (a technical proposal)
- JCTVC-D416 (a non-normative technical proposal, considered acceptable for action due to its non-normative nature)
- JCTVC-D421 (a technical proposal, adopted as an exceptional instance of agreement to accept taking action such a late proposal)
- JCTVC-D432 (a technical proposal, adopted as the appropriate action upon consideration of several contributions of a similar nature)
- JCTVC-D438 (a technical proposal)
- JCTVC-D448 (a joint technical proposal submitted in response to CE discussions)

Except as noted above, no action was taken in response to these late technical proposals (other than designation for further study in some cases).

Late CE results, cross-verification reports, and similar documents included the following:

- JCTVC-D068 (a cross-verification report)
- JCTVC-D098 (a CE results report)
- JCTVC-D144 (a CE results report)
- JCTVC-D145 (a CE results report)
- JCTVC-D146 (a CE results report)
- JCTVC-D147 (a cross-verification report)
- JCTVC-D148 (a cross-verification report)
- JCTVC-D149 (a CE summary report)
- JCTVC-D161 (a CE results report)
- JCTVC-D194 (a CE results report)

- JCTVC-D247 (a cross-verification report)
- JCTVC-D406 (a cross-verification report)
- JCTVC-D407 (a cross-verification report)
- JCTVC-D408 (a cross-verification report)
- JCTVC-D413 (a CE results report)
- JCTVC-D414 (a CE results report)
- JCTVC-D415 (a CE results report)
- JCTVC-D417 (a cross-verification report)
- JCTVC-D418 (a CE results report)
- JCTVC-D419 (a CE results report)
- JCTVC-D420 (a CE results report)
- JCTVC-D422 (a CE results report)
- JCTVC-D423 (a CE results report)
- JCTVC-D424 (a CE results report)
- JCTVC-D425 (a cross-verification report)
- JCTVC-D426 (a cross-verification report)
- JCTVC-D427 (a CE results report)
- JCTVC-D428 (a cross-verification report)
- JCTVC-D429 (a cross-verification report)
- JCTVC-D430 (an information document similar to a cross-verification report)
- JCTVC-D431 (a cross-verification report)
- JCTVC-D433 (a cross-verification report)
- JCTVC-D434 (a cross-verification report)
- JCTVC-D435 (a cross-verification report)
- JCTVC-D436 (a cross-verification report)
- JCTVC-D437 (a cross-verification report)
- JCTVC-D439 (a cross-verification report)
- JCTVC-D442 (a cross-verification report)
- JCTVC-D444 (a cross-verification report)
- JCTVC-D446 (a CE results report)
- JCTVC-D449 (a cross-verification report)
- JCTVC-D450 (a cross-verification report)
- JCTVC-D451 (a bug fix report)
- JCTVC-D452 (a cross-verification report)
- JCTVC-D453 (a cross-verification report)

- JCTVC-D454 (a cross-verification report)
- JCTVC-D455 (a cross-verification report)
- JCTVC-D456 (a cross-verification report)

Ad hoc group activity and results reports, break-out activity reports, and information documents containing results of experiments requested during the meeting are not included in this list, as these are considered administrative report documents.

Documents with numbers JCTVC-D413 through JCTVC-D458 were classified as late registrations (except for administrative report documents as discussed above).

As a general policy, missing documents were not to be presented, and late documents (and substantial revisions) could only be presented when sufficient time for studying was given after the upload. An exception is given for AHG reports and CE summaries which can only be produced after availability of other input docs. There were no objections raised by the group regarding presentation of late contributions. The situation about missing input documents must be significantly improved in upcoming meetings.

"Placeholder" contribution documents that were basically empty of content, with perhaps only a brief abstract and some indication of an intent to provide a more complete submission as a revision, were considered unacceptable and rejected in the document management system, as agreed at the third meeting.

The initial uploads of the following contribution documents were rejected as placeholders and not corrected until after the upload deadline:

- JCTVC-D129 (replaced by a more acceptable version on Wednesday 19th, before meeting)
- JCTVC-D307 (replaced by a more acceptable version on Monday 17th, before meeting)

The initial uploads of the following contributions appeared as if they might be borderline in terms of "placeholder" acceptability of the initial uploaded version, but were not rejected as placeholders:

- JCTVC-D297 (initially uploaded on 15th, revised on 22nd and 27th)
- JCTVC-D311 (initially uploaded on 15th, revised on 19th and 20th)
- JCTVC-D379 (initially uploaded on 16th, revised on 20th and 25th)
- JCTVC-D386 (initially uploaded on 16th, revised on 22nd)
- JCTVC-D397 (initially uploaded on 16th, revised on 20th)
- JCTVC-D413 (initially uploaded on 18th, revised on 20th and 22nd)

A few contributions 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 all cases (to the extent of the awareness of the chairs).

1.4.3 Measures to facilitate the consideration of contributions

It was agreed that, due to the increasingly high workload for this meeting, the group would try to rely more extensively on summary CE reports. For other contributions, it was agreed that generally presentations should not exceed 2 slides and 5 minutes to achieve a basic understanding of a proposal – with further review only if requested by the group. For cross-verification contributions, it was agreed that the group would ordinarily only review cross-checks for proposals that appear promising.

When considering cross-check contributions, it was agreed that, to the extent feasible, the following data should be collected:

- Subject (including document number).
- Whether common conditions were followed.

- Whether the results are complete.
- Whether the results match those reported by the contributor (within reasonable limits, such as minor compiler/platform differences).
- Whether the contributor studied the algorithm and software closely and has demonstrated adequate knowledge of the technology.
- Whether the contributor independently implemented the proposed technology feature, or at least compiled the software themselves.
- Any special comments and observations made by the cross-check contributor.

1.4.4 Outputs of the preceding meeting

The report documents of the previous meeting, particularly the meeting report JCTVC-C400, the HEVC Test Model (HM) JCTVC-C402, and the Working Draft (WD) JCTVC-C403 were approved. The HM reference software produced by the AHG on software development and HM software technical evaluation was also approved.

1.5 Attendance

The list of participants in the JCT-VC 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 JCT1/SC29/WG11 (including experts who had been personally invited by the Chairs 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 Chairs.

1.6 Agenda

The agenda for the meeting was as follows:

- IPR policy reminder and declarations
- Contribution document allocation
- Reports of Ad Hoc group activities
- Reports of Core Experiment activities
- Review of results of previous meeting
- Consideration of contributions and communications on HEVC project guidance
- Consideration of HEVC technology proposal contributions
- Consideration of information contributions
- Coordination activities
- Future planning: Determination of next steps, discussion of working methods, communication practices, establishment of coordinated experiments, establishment of AHGs, meeting planning, refinement of expected standardization timeline, other planning issues
- Other business as appropriate for consideration

1.7 IPR policy reminder

Participants were reminded of the IPR policy established by the parent organizations of the JCT-VC and were referred to the parent body web sites 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. Contributions of software source code for incorporation into the Reference Software for the standard shall be provided with a suitable copyright disclaimer header text in a form acceptable to the parent bodies to enable publication of the source code and to enable users of the software to copy the software and use it for research and standardization purposes and as a basis for the development of products.(while the submitter separately retains any associated patent rights for licensing to be conducted outside of ITU-T/ITU-R/ISO/IEC).

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 JCT-VC as 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/jctvc-site (JCT-VC contribution templates)
- http://www.itu.int/ITU-T/studygroups/com16/jct-vc/index.html (JCT-VC founding charter)
- http://www.itu.int/ITU-T/dbase/patent/index.html (ITU-T IPR database)
- http://www.itscj.ipsj.or.jp/sc29/29w7proc.htm (SC29 Procedures)

The chairs invited participants to make any necessary verbal reports of previously-unreported IPR in draft standards under preparation, and opened the floor for such reports: No such verbal reports were made.

It was mentioned that further discussions about an appropriate software disclaimer header text are currently being conducted between JCT-VC and parent body management, as discussed in JCTVC-B001, JCTVC-C001 and JCTVC-D001. To proceed on this, JCT-VC had issued the following resolution to the WG11 parent body at its previous meeting: "The JCT-VC has requested review of the reference software copyright handling status reported from the JCT-VC chairs as found in N11645 [a document produced for WG11 corresponding to the content of JCTVC-C001]. NBs are requested to comment on the suitability of the proposed approaches."

1.8 Communication practices

The documents for the meeting can be found at http://phenix.it-sudparis.eu/jct/. This is a relatively new site that the group transitioned to using just prior to the preceding meeting. Previously, JCT-VC documents had been made available at http://ftp3.itu.int/av-arch/jctvc-site, and documents for the first two JCT-VC meetings can be found there. That site was also used for distribution of the contribution document template and circulation of drafts of this meeting report.

JCT-VC email lists are managed through the site http://mailman.rwth-aachen.de/mailman/options/jct-vc, and to send email to the reflector, the email address is jct-vc@lists.rwth-aachen.de. Only members of the reflector can send email to the list.

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

For the case of TE/CE documents and AHGs, email addresses of participants and contributors may be obscured or absent (and will be on request), although these will be available (in human readable format – possibly with some "obscurification") for primary TE/CE coordinators and AHG chairs.

1.9 Terminology

Some terminology used in this report is explained below:

- **AHG**: Ad hoc group.
- **AI**: All-intra.
- **AIF**: Adaptive interpolation filtering.
- **AIS**: Adaptive intra smoothing.
- **ALF**: Adaptive loop filter.
- **AMP**: Asymmetric motion partitioning.
- **AMVR**: Adaptive motion vector resolution.
- **AVC**: Advanced video coding – the video coding standard formally published as ITU-T Recommendation H.264 and ISO/IEC 14496-10.
- **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).
- **BoG**: Break-out group.
- **BR**: Bit rate.
- **CABAC**: Context-adaptive binary arithmetic coding.
- **CBF**: Coded block flag(s).
- **CE**: Core experiment – a coordinated experiment conducted after the 3rd or 4th meeting.
- **DCT**: Discrete cosine transform (sometimes used loosely to refer to other transforms with conceptually similar characteristics).
- **DCTIF**: DCT-derived interpolation filter.
- **DIF**: Directional interpolation filter.
- **DF**: Deblocking filter.
- **DT**: Decoding time.
- **ET**: Encoding time.
- **GPB**: Generalized P/B – a not-particularly-well-chosen name for B pictures in which the two reference picture lists are identical.
- **HE**: High efficiency – a set of coding capabilities designed for enhanced compression performance (contrast with LC). Often loosely associated with RA.
- **HEVC**: High Efficiency Video Coding – the video coding standardization initiative under way in the JCT-VC.

- **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).
- **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).
- **JM**: Joint model – the primary software codebase developed for the AVC standard.
- **LC**: Low complexity – a set of coding capabilities designed for reduced implementation complexity (contrast with HE). Often loosely associated with LD.
- **LCEC**: Low-complexity entropy coding.
- **LD**: Low delay – a set of coding conditions designed to enable interactive real-time communication, with less emphasis on ease of random access (contrast with RA). Often loosely associated with LC.
- **LUT**: Look-up table.
- **MC**: Motion compensation.
- **MDDT**: Mode-dependent directional transform.
- **MPEG**: Moving picture experts group (WG 11, the parent body working group in ISO/IEC JCT 1/SC 29, one of the two parent bodies of the JCT-VC).
- **MRG**: block merging mode for CUs.
- **MV**: Motion vector.
- **NAL**: Network abstraction layer (as in AVC).
- **NB**: National body (usually used in reference to NBs of the WG11 parent body)
- **OBMC**: Overlapped block motion compensation.
- **PCP**: Parallelization of context processing.
- **PIPE**: Probability interval partitioning entropy coding (roughly synonymous with V2V for most discussion purposes, although the term PIPE tends to be more closely associated with proposals from Fraunhofer HHI while the term V2V tends to be more closely associated with proposals from RIM).
- **QP**: Quantization parameter.
- **QT**: Quadtree
- **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). Often loosely associated with HE.
- **R-D**: Rate-distortion.
- **RDO**: Rate-distortion optimization.
- **RDOQ**: Rate-distortion optimized quantization.
- **ROT**: Rotation operation for low-frequency transform coefficients.
- **RQT**: Residual quadtree.
- **SEI**: Supplemental enhancement information (as in AVC).
- **TE**: Tool Experiment – a coordinated experiment conducted after the 1st or 2nd JCT-VC meeting.

- **TM**: Test Model – a video coding design containing selected coding tools; as contrasted with the TMuC, see HM.
- **TMuC**: Test Model under Consideration – a video coding design containing selected proposed coding tools that are under study by the JCT-VC for potential inclusion in the HEVC standard.
- **TPE**: Transform precision extension.
- **UDI**: Unified directional intra.
- **Unit types**:
  - **CU**: coding unit.
  - **LCU**: (formerly LCTU) largest coding unit (synonymous with TB).
  - **PU**: prediction unit, with four shape possibilities.
    - **2Nx2N**: having the full width and height of the CU.
    - **2NxN**: having two areas that each have the full width and half the height of the CU.
    - **Nx2N**: 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.
  - **TB**: tree block (synonymous with LCU – LCU seems preferred).
  - **TU**: transform unit.
- **V2V**: variable-length to variable-length prefix coding (roughly synonymous with PIPE for most discussion purposes, although the term PIPE tends to be more closely associated with proposals from Fraunhofer HHI while the term V2V tends to be more closely associated with proposals from RIM).
- **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 JCT-VC).
- **WD**: Working draft – the draft HEVC standard corresponding to the HM.
- **WG**: Working group (usually used in reference to WG 11, a.k.a. MPEG).

1.10 Liaison activity

The JCT-VC did not send or receive formal liaison communications at this meeting.

1.11 Contribution topic overview

The approximate subject categories and quantity of contributions per category for the meeting were summarized and categorized into "tracks" (A, B, or P) for parallel or plenary review, as follows.

- AHG reports (13) Track P (P = "plenary", 1st Thurs.)
- Project guidance (3) Track P (Monday)
- CE summary reports (13) – Reviewed with individual CE-related contributions
- CE1: Decoder-side motion vector derivation (12) Track A (Chair: G. J. Sullivan)
- CE2: Flexible motion partitioning (9) Track A
- CE3: Interpolation filtering for MC (luma) (25) Track A

- CE4: Interpolation filtering for MC (chroma) (15) Track A
- CE5: Low complexity entropy coding improvements (11) Track B (Chair: J.-R. Ohm)
- CE6: Intra prediction improvement (20) Track B
- CE7: Alternative transforms (24) Track B
  BoG on spatial transforms "Baeto" room (at end of first meeting day, and also at some other times)
- CE8: In-loop filtering (22) Track A
  informal subjective viewing for CE8 subtest 1 deblocking and debanding subjective viewing (initial viewing without scoring) "Arte" room 3pm on first day, and also at some later times
- CE9: Motion vector coding (23) Track A
- CE10: Number of intra prediction directions (8) Track B
- CE11: Coefficient scanning and coding (16) Track B
- CE12: Adaptive motion vector resolution (6) Track A
- CE13: Intra smoothing (8) Track B
- Project planning & NB comments (3) Track P (Mon 5pm)
- HM settings and common test conditions (8) Track A
  (after IBDI – including screen coding/guidance)
- Test material (3) Track A
- Application-specific topics (7) Track B
- Loop filtering (15) Track A
  (with CE8, after common conditions & test material)
- Block structures and partitioning (12) Track B
- Motion compensation and interpolation filters (9) Track A
- Motion vector coding (17) Track A
- Inter mode coding (10) Track A
- High-level syntax (11) Track A
- Quantization (7) Track B
- Entropy coding (17) Track B
- Intra prediction and mode coding (22) Track B
- Transforms and residual coding (31) Track B
- IBDI and memory compression (11) Track A
- Complexity analysis (0)
- Category not clear (1)

2 AHG reports

The activities of *ad hoc* groups that had been established at the prior meeting are discussed in this section.

JCTVC-D001 JCT-VC AHG report: Project management [J.-R. Ohm, G. J. Sullivan (AHG Chairs)] (missing prior, uploaded 20th, first day)

(Reviewed verbally prior to upload.)

The work of the JCT-VC overall had proceeded well in the interim period. A large amount of discussion was carried out on the group email reflector. All report documents from the preceding meeting had been made available, particularly including the following:

- The meeting report (JCTVC-C400)
- Summary of HEVC working draft 1 and HEVC test model (HM) JCTVC-C405 [finalized 15 Oct.]
- The HEVC Working Draft (JCTVC-C403) [delivered later than originally planned – 15 Jan.]
- The HM encoder description (JCTVC-C402) [delivered later than originally planned – 6 Jan.]
- Finalized core experiment descriptions (JCTVC-C501 through JCTVC-C513)

The various ad hoc groups and tool experiments have made progress and various reports from those activities had been submitted.

The status of work on the software copyright issue remained essentially unchanged since the last meeting.

As some time has passed since the alternative wording above was initially circulated for review at the previous meeting, participants were encouraged to use the current meeting as an opportunity to review the status as reported previously. A final decision should be made in coordination with the parent bodies during the 5th meeting in March 2011.

JCTVC-D002 JCT-VC AHG report: HEVC Draft and Test Model editing [K. McCann, T. Wiegand (co-chairs), B. Bross, W.-J. Han, J.-R. Ohm, J. Ridge, S. Sekiguchi, G. J. Sullivan (vice chairs)] (missing prior, uploaded 19th, before meeting)

This document reported on the work of the JCT-VC ad hoc group on HEVC Draft and Test Model editing between the 3rd JCT-VC meeting in Guangzhou, China (7-15 October 2010) and the 4th JCT-VC meeting in Daegu, Korea (20-28 January 2011).

Both the JCTVC-C402 and JCTVC-C403 documents were produced, each in a single draft.

In the case of JCTVC-C402, the document was a rough skeleton that still required significant improvement. There was very little text from the corresponding TMuC document, JCTVC-B204, that was deemed to be appropriate to be incorporated. A structure was adopted where the main body of the document was split into two parts.

- Section 5 as the test model description, giving a general tutorial overview of the architecture
- Section 6 as the encoder description, giving details of the encoder

In the case of JCTVC-C403, the document was a more complete draft, that:

- Incorporated text from JCTVC-B205 revision 7
- Incorporated the decisions on high-level syntax according to JCTVC-B121
- Incorporated text from JCTVC-C319 (as found to be stable)
- Revised coding tree, coding unit and prediction unit syntaxes
- Included initial drafting of decoding process of coding units in intra prediction mode (luma part, JCTVC-B100 and JCTVC-C042)
- Included initial drafting of decoding process of coding units in inter prediction mode
- Included initial drafting of scaling and transformation process

- Added text, transform 16T and 32T
- Included initial drafting of deblocking process
- Improved text on derivation process for motion vector components and reference indices
- Added text on boundary filtering strength

Open issues for JCTVC-C403 remained:

- Substantial portions of JCTVC-B205 have not been imported so far, as they require significant editorial work
- The question over whether support for monochrome, 4:2:2 and 4:4:4 (with and without separate color planes) be included from the start? Currently, it has been left in the text as it doesn't seem to affect much text.
- Handling of the term "frame". One suggestion would be to change all occurrence of "frame" to "picture" (all occurrences of "field" will be removed)
- Large size table (zig-zag and de-scaling matrices) is not inserted yet.
- Slice-header syntaxes and their semantics are not included yet. Also possible modifications that may be necessary because of larger treeblocks (64x64) compared to macroblocks (16x16) are not yet considered.
- ALF, VLC and IBDI process is not included yet.
- Text representing entropy coding named as "LCEC" is missing. The name LCEC may need to be adjusted. Currently, there is a place holder with CAVLC.
- Text representing CABAC entropy coding needs to be extended.

The recommendations of the HEVC Draft and Test model Editing AHG were to:

- Approve the edited JCTVC-C402 and JCTVC-C403 documents as JCT-VC outputs
- Continue to edit the HEVC WD and Test Model documents to ensure that all agreed elements of HEVC are fully described
- Compare the HEVC documents with the HEVC software and resolve any discrepancies that may exist, in collaboration with the Software AHG
- Continue to improve the editorial consistency of HEVC WD and Test Model documents

During the discussion of this report, it was suggested and agreed that, in the future, post-meeting output document availability should be announced on the reflector.

JCTVC-D003 JCT-VC AHG report: Software development and HM software technical evaluation [F. Bossen, D. Flynn, K. Sühring (AHG Chairs)] (missing prior, uploaded 20th, first day)

(Reviewed verbally prior to upload.)

This report summarized the activities of the AhG on Software development and HM software technical evaluation that have taken place between the 3rd and 4th JCT-VC meeting. Activities included integration of tools into a common code base, removal of tools not included in HM, bug fixes, etc. A "stripped" version of HM software (i.e., with removal of non-HM/WD features) had been made available.

The reference software manual was sent via reflector and was registered as JCTVC-D404 (see below).

Version 0.9 of the software was delivered according to schedule and reference configuration encodings were provided according to the common test conditions. This software version was used in the CEs. HM software V1.0 was made available shortly before meeting. The number of code lines had been reduced to approximately 50 000 compared to 100 000 in the previous TMuC and V0.9 software.

Bug fixing and some potential mismatches with the WD text were also reported.

During the presentation, particular attention was brought to the fact that the LCEC implementation currently only supports the default tree depth of the LC configuration (if set differently, the performance drops, and the software also prints a warning message). Further, the high-level syntax implementation currently was not matching with the WD text.

JCTVC-D404 HEVC Reference Software Manual [F. Bossen, D. Flynn, K. Suehring (AHG chairs)] (missing prior, uploaded Thursday 20th, first day of the meeting)

This helpful document described how to use the HEVC reference software, and was provided for information as AHG activity report output.

JCTVC-D004 JCT-VC AHG report: Slice support development and characterization [Rickard Sjöberg (AHG chair)] (missing prior, uploaded 19th, before meeting)

This report summarized the slice support development and characterization ad-hoc activities between the 3rd and the 4th JCT-VC meeting and the input documents to this meeting related to this ad-hoc group. The work had progressed well, and the AHG recommended to integrate the resulting slice source code from TMuC version 0.9 into the HM software and to review the relevant input documents.

The report provided some experiment results regarding the coding efficiency impact of slice structured coding with a fixed maximum byte limit per slice. Enforcing a 1500 byte limit resulted in 2-5% coding efficiency impact, depending on the test configuration case, and also a few percent impact on runtimes of the encoder and decoder.

A temporary mailing list for detail work on software implementation of slice support had been announced by the AHG chair on the JCT-VC general email reflector on 26 November (while more general discussion relating to the topic was continued on the main JCT-VC email reflector). The AHG chair indicated that the continued use of that temporary reflector was not planned. It was remarked that in the future, the establishment of additional reflector for AHG activities should be something that is planned in advance and recorded at the preceding meeting.

In the current implementation, large CUs may be encoded twice when they need to be split in two slices – this particularly can happen more frequently for intra coding.

About the relation of the slice implementation with the WD: No input contribution to this meeting provides a text describing the current implementation. Regarding the request of the AHG to adopt the implementation into HM software, this is agreed to make a step forward; however it is emphasized that ideally a clear idea about the normative specification should exist before; this is necessary to be provided in the interim period until the next meeting and requires more careful study.

JCTVC-D005 JCT-VC Ad Hoc Report: Spatial Transforms [Pankaj Topiwala, Robert Cohen, Madhukar Budagavi, Rajan Joshi]

The purpose of this AhG was to study the transforms in the HM design, including compression performance, computational complexity, dynamic range, storage requirements, etc.

The submission of a number of contributions relating to the work of the AhG was noted, and various aspects of the complexity of transform designs were discussed (arithmetic complexity, parallelism, memory and memory bandwidth, dynamic range, etc.). It was recommended to review the relevant contributions and continue the work, including considering the establishment of one or more CEs.

A BoG activity was planned to review related inputs, coordinated by P. Topiwala, to meet in the JCT-VC break-out room after the close of the main JCT-VC session on the first day of the meeting (Thursday 20 January). This was later postponed to Friday at 1pm (see results of BoG in JCTVC-D445).

JCTVC-D006 JCT-VC AHG report: In-loop and post-processing filtering [T. Yamakage, K. Chono, Y. J. Chiu, I. S. Chong, M. Narroschke (AHG Chairs)] (missing prior, uploaded 19th, before meeting)

This AHG report reviewed the status of work and incoming contributions submitted on the subject of in-loop and post-processing filtering. There had not been very much email discussion of this subject on the email reflector in the interim period. It was noted that there were eight technical proposals to the Daegu meeting related to this AHG and nine technical proposals related to CE8 on in-loop filtering. Most of the mandates of this AHG were covered by CE8 contributions.

JCTVC-D007 JCT-VC AHG report: Coding block structures [K. Panusopone, W.-J. Han, T. K. Tan, T. Wiegand (AHG Chairs)] (missing prior, uploaded 18th, before meeting)

This report summarized the Coding block structures Ad hoc activities between the 3nd JCT-VC meeting in Guangzhou, China (7 to 15 October, 2010) and the current 4th JCT-VC meeting in Daegu, Korea (20 to 28 January, 2011). The current design of coding block structures in the WD was reviewed in the report.

The HM (as of the output of the Guangzhou meeting) uses a quadtree (QT) data structure to represent various possible CU(s) within a LCU. Given a CU, HM allows TU with various sizes. A separate QT is used to represent the possible TU(s) within a CU (RQT, residual quadtree). Both QT representations need to be coded as overhead. The CU QT is per LCU and the RQT is per CU.

QT configuration in HM environment is controlled via three parameters: maximum size, minimum size, and tree depth.

- Maximum size determines the largest coverage area of a QT node and it corresponds to the top level of the QT.
- Minimum size determines the smallest coverage area of a QT node and it corresponds to the bottom level of the QT.
- Tree depth determines the maximum depth allowed for the QT, but it is further controlled by the minimum sizes (the tree can't be split further when its leaf reaches the minimum size).

To balance the trade-off between compression performance and complexity, certain constraints are applied to RQT structure. Specifically, the maximum TU size is set equal to the the minimum of the CU size and the maximum supported transform block size (e.g., 32x32). The depth of RQT determines the minimum size of a TU relative to the maximum size. Currently, the maximum tree depth is set to 3 for the high efficiency (HE) configuration and 2 for the low complexity (LC) configuration.

The trade-off between the flexibility of a QT and its overhead has to be managed carefully in order to achieve high compression performance. In order to understand more about QT overhead, some experiment data was provided to show the quantity of CU, TU, and PU overhead (in term of percentage of the entire bitstream) for random access and low delay conditions, respectively.

There were other activities relating to the Coding block structure AhG that occurred between the Guangzhou meeting and the Daegu meeting. CE2 studied several flexible motion partitioning methods which will impact PU partitioning. Several companies had conducted independent investigations of RQT and PU and their findings were reported to the group through the JCT-VC reflector. TI and Sony have done a joint study on RQT. Their study compared the RQT coding efficiency with the TMuC0.7 two-level method, and found that the gain of RQT is marginal. They also reported some loss in the chroma component of all the configurations for RQT. Further study on RQT and its alternatives may provide insight into the way to improve TU tree representation.

LG and DOCOMO had independently looked into a trade-off between complexity and coding efficiency of PU partitioning. Their studies focus on the effect of removing NxN PU partitioning except when the

CU size is minimum in both intra prediction and inter prediction and their results reportedly show that their proposed PU partitioning suffers slight coding efficiency loss while reducing encoding time noticeably. The study of partial NxN PU partitioning removal is also a subject of the CE9 experiment.

Five relevant contributions submitted to the current meeting were noted. The recommendations of the Coding block structures AhG were to:

- Study TU tree partitioning method including RQT optimization and implicit TU representation.
- Study redundancy in PU partitioning including impact of NxN PU partitioning removal when CU size is not the minimum size.
- Encourage more people to volunteer to contribute on improving coding efficiency and simplification of Coding block structures.

During the discussion, it was remarked that there is some degree of redundancy between the ability to divide PUs and TUs and the ability to divide CUs.

Removal of the redundancy between the NxN PU segmentation within a CU and the segmentation of a CU into four smaller CUs would mainly be beneficial in saving encoder time.

JCTVC-D008 JCT-VC AHG report: Reference pictures memory compression K. Chono, T. Chujoh, C. S. Lim, A. Tabatabai, M. Zhou (missing prior, uploaded 18th, before meeting)

This document summarized the AHG activities between the 3rd JCT-VC meeting in Guangzhou, CN (7-15 October, 2010) and the current 4th Meeting: Daegu, KR, 20-28 January, 2011.

TI and NEC had reportedly improved the run-time memory access module used in TE2 and integrated the improved version into the TMuC0.9 branch.

It was reported that for low delay results, the average of the memory access bandwidth was increased by about 25% compared to that of the TMuC0.7 anchor encoded streams. One of the major reasons was reportedly that the TMuC0.9 anchor streams contained more "skip" and "direct" modes associated with bi-prediction than in TMuC0.7, due to the introduction of the "SAMSUNG_MRG_SKIP_DIRECT" modification.

JCTVC-D045 and JCTVC-D152 independently investigated an anomalous coding efficiency loss caused by fixed rounding of extended bit depth values, and it was reported that the Sum of Squared Errors (SSE) computation of the current TMuC software is unconscious with quantization error associated with the fixed rounding of extended bit depth values. Contributions, JCTVC-D156 and JCTVC-D281 are their cross-verification reports.

It was reported that JCTVC-D023 analyzed the problem and proposed improved memory compression schemes based on Toshiba’s Dynamic Range Adaptive Scaling.

It was reported that JCTVC-D025 investigates IBDI performance when the reference frames are stored in 8-bits per sample.

It was reported that in JCTVC-D086 Panasonic and NEC jointly studied visual quality impact of decoder-side reference picture memory compression in order to allow decoders to use memory compression schemes with minimum visual quality degradation, and it reportedly demonstrated benefits of using constrained intra prediction in reducing visual artifacts.

It was reported that JCTVC-D152 suggested that the definition of distortion associated with lossy processing is the appropriate scope of standardization for memory compression since the parts of lossless coding and bitstream format on frame memory do not cause encoder-decoder mismatch. It also presented a memory compression scheme based on the concept.

It was reported that JCTVC-D023, JCTVC-D035, JCTVC-D152, and JCTVC-D280 present new results of memory compression in TMuC0.9.

The report noted the relevant contributions that had been submitted to the current meeting.

The recommendations of the AHG were to:

- Adopt the run-time memory access modules to HM software as an macro to be turn on or off by compilation
- Study the benefit of error resilience tools such as constrained intra prediction, etc., in reducing visual artifacts with different decoder-side memory compression schemes

JCTVC-D009 JCT-VC AHG report: Entropy coding [M. Budagavi, G. Martin-Cocher, A. Segall (AHG Chairs)] (missing prior, uploaded 18th, before meeting)

There was no email activity related to this AhG on the JCTVC reflector. But several AhG members interested in this area were actively participating in proposal/cross-verification of entropy coding within CE5 and CE11.

There were several contributions to the Daegu meeting that related to the mandates of this Ad Hoc Group. They were broadly categorized as follows:

- LCEC related contributions
- CE5 (Low Complexity Entropy Coding Improvements) related contributions
- Context processing related contributions
- CE11 (Coefficient Scanning and Coding) related contributions
- PIPE/V2V related contributions
- Others

A summary of the contributions was provided in the report.

JCTVC-D010 JCT-VC AHG report: Entropy slices A. Segall, V. Sze, Y.-W. Huang (missing prior, uploaded 20th, firstday)

This report summarized the activities of the Ad Hoc Group on Entropy Slices between the 3rd JCT-VC meeting held in Guangzhou in October 2010 and the current meeting in Daegu. Three input contributions (JCTVC-D070, JCTVC-D073 and JCTVC-D243) were noted to be related. The AHG also provided data about the performance loss if the conventional slice concept (as developed under the slice AHG) is used for the purpose of invoking parallel processing capability. The Y BD rates were increased by 3.6%, 7.1% and 8.4% for AI, RA and LD HE configurations under certain assumptions regarding how pictures were segmented into slices. It is claimed that the rate increase by invoking slice capabilities only for the purpose independent (parallel) entropy decoding is significantly less (as per the contributions). Continuation of the study was recommended.

JCTVC-D011 JCT-VC AHG report: Video test material selection [T. Suzuki (AHG chair)] (missing prior, uploaded 18th, before meeting)

This AHG was established in Guangzhou to collect and study test materials for the development of HEVC.

It was suggested to change the test sequence selections to have a larger variation or 'wide coverage' of natural video. Particularly, the following issues were mentioned as critical.

- The current class A test set was reported to be insufficient to evaluate coding performance for high resolution video, especially UHDTV (contents are still 30fps only, does not contain drastic motion etc.), even though UHDTV has been recognized as an important application domain for HEVC. It is, however, important to note that JCT-VC has started formal CE activities, which means that set-up of a better test set should be an urgent issue.

- It was proposed to consider cropped versions of Super Hi-Vision sources donated by NHK in JCTVC-A023 as additional class A test sequences. Results were presented by NHK in JCTVC-C055, which showed that cropping SHV source to class A size did not practically affect coding performance evaluation compared to full-8K resolution. This was demonstrated both subjectively and objectively at Guangzhou. The question was raised by one expert if it would not be better to use down-sampled versions of the 8K sequences, which might also partially resolve the problem that the sequences (particularly Nebuta) are rather noisy. Th answer was that this would change the sequence characteristics which are specific for (currently available) 8K material, which might not be desirable.

- The current test sets don't include fast motion (at least in classes A and B). The coding performance is improved by more than 2% BR reduction for the Steam Locomotive sequence when a larger search range is used. Therefore, setting the MV search range to 128x128 was recommended for testing of SHV sequences.

- The Vidyo sequences in the common test set have some issues. All Vidyo sequences are slightly trembling vertically which is visible in chroma components (visible when sequences are magnified). It was questioned if this represents common characteristics for video conferencing systems. This could be a reason to cause a loss in chroma components in LD cases reported on the performance of TMuC 0.7 vs 0.9. One expert mentioned that the chroma artifacts could be be due to the in-camera compression which was used when the sequences were shot. Indeed, camera compression might be a typical characteristic, as often low-cost HD cameras do not provide a way to turn it off.

Activities to collect new test material are going on. Initial contacts have been made to explore the possibility of getting some CG content and some HDTV captured by the latest camera systems. However, permission to use these materials for HEVC development has not been granted yet. This activity should be continued.

The report noted the related contributions to the meeting.

It was further remarked that the limitation of 32x32 transform size for luma results in having a maximum transform size of 16x16 for 4:2:0 chroma, which may affect DC offset behavior.

JCTVC-D012 JCT-VC AHG report: Complexity assessment [D. Alfonso (chair), J. Ridge, X. Wen (vice-chairs)]

This report summarized the activities of the Ad Hoc Group on Complexity Assessment between the 3rd JCT-VC meeting held in Guangzhou in October 2010 and the current meeting in Daegu. The discussions on the email reflector and work of relevant other AhGs were noted.

The Complexity Assessment AHG recommended the following:

- To review and compare the complexity results reported by the other Ad-Hoc Groups.

- To consider the possibility to harmonize the different complexity assessment methodologies in a common method shared among the various groups.

- To continue discussions among JCT-VC experts to reach consensus on suitable complexity definitions and methods to measure it.

- To continue complexity assessment experiments in order to further optimize the trade-off between complexity and coding efficiency in the new HM software.

JCTVC-D013 JCT-VC AHG report: Motion compensation interpolation [K. Ugur, E. Alshina, P. Chen, T. Chujoh (AHG Chairs)] (missing prior, uploaded 20th, the first day of the meeting)

For this AhG, the related CEs and input documents relating to motion compensation interpolation were reviewed. Two Core Experiments (CE3 and CE4) had been established in Guangzhou to study performance and complexity of various luma and chrominance interpolation filters. The additional non-CE relevant input contributions were reviewed in the report.

3 Project guidance

3.1 Screen content coding

JCTVC-D021 USNB Contribution: Response to WG11 resolution 10.1.3 of the 94th meeting [A. G. Tescher for USNB of WG11]

In response to WG11 resolution 10.1.3 of the 94th WG11 meeting, the USNB of WG11 responded as follows:

- The USNB of WG11 responds affirmatively that it does expect "screen content" to be prevalent in the use of HEVC.
- USNB of WG11 suggested considering the category of such "screen content" to include animation/rendered video content as well as the examples mentioned in resolution 10.1.3 of the 94th WG11 meeting.
- USNB of WG11 requested WG11 to collect representative content.
- USNBof WG11 indicated that it believes that it would be valuable to study the subject and characterize the behavior of the draft standard on such content, and that the behavior of the draft HEVC design on such content should be considered in the technical work.

JCTVC-D028 JNB comments on WG11 Resolution 10.1.3: Coding of screen content [JNB of WG11]

- JNB of WG 11 requested to clarify the necessity of the standardization of the screen content coding as a part of HEVC.
  - JNB of WG 11 indicated that most of such coding technologies are expected to be effective only for screen content and not to be used for the other HEVC applications, and recommended to do it as another part of MPEG standards rather than as a part of HEVC.
- JNB of WG 11 requested to clarify the requirements on the coding of screen content.
  - JNB of WG 11 indicated that 4:4:4 colour format is supposed to be necessary for such a content, and recommended to consider the screen content together with 4:4:4 colour format for the future extension of HEVC.
- JNB of WG 11 requested to solve the following concerns if and when the JCT-VC decided to add the coding of screen content into the HEVC requirements:
  - JNB of WG 11 requested that HEVC standardization time line should be kept as agreed in Guangzhou ('12/02 CD, '12/07 DIS, '13/01 FDIS)
  - JNB of WG 11 requested that the complexity of HEVC should not be unnecessarily increased by the adoption of coding tools which are effective only for the screen content.

3.2 Software copyright disclaimer text

JCTVC-D022 USNB Contribution: Response to WG11 resolution 10.1.4 of the 94th meeting [A. G. Tescher for USNB of WG11]

In response to WG11 resolution 10.1.4 of the 94th WG11 meeting, the USNB of WG11 agreed with the spirit of the conclusions and recommendations expressed in WG11 N11645 [a document produced for

WG11 corresponding to the content of JCTVC-C001] in regard to software copyright for HEVC reference software development.

3.3 Discussion with MPEG Requirements and Video

A discussion of these subjects was held as a joint session with the MPEG Requirements and Video sections.

In a discussion of the screen coding coding topic, it was noted that the WG 11 NBs of Finland, China and the US consider "screen content" coding within the scope of HEVC. The view of the Japan NB is recorded above. After discussion, it was agreed that screen content is considered within the scope, but it should not become a major focus in the work, must not cause a schedule delay, and must not put complex features in "mainstream" profile(s) that are only for that purpose.

The subject of bitstream scalability was also discussed – e.g., temporal & spatial scalability, chroma format scalability between 4:4:4/4:2:2/4:2:0, and similar things.

After discussion, it was agreed that these capabilities are desirable for HEVC (including for its first version), but that work on these topics should not affect the timeline (or become a major distraction).

It was agreed that WG11 would revise its requirements document stating its views on the requirements for HEVC. This document was issued by WG11 as a public WG 11 output document N11872, which was made publicly available at http://mpeg.chiariglione.org/working_documents/mpeg-h/vision-apps-reqs.zip.

The VCEG requirements document regarding the project already indicated that support for bitstream scalability was desirable, and VCEG had previously expressed its view that screen content coding should be considered within the scope of the work. The VCEG requirements document was not further reviewed in the discussions at the meeting.

In regard to the software copyright disclaimer, it was noted that the USNB of WG 11 was supportive of the spirit of the previously-expressed conclusions and recommendations. The status on this topic was otherwise essentially unchanged since that reported at the preceding meeting.

There was no disagreement regarding the suggestion that JCT-VC may move forward with using one of the two suggested wordings and removing other copyright wordings from the software. Action on the topic was deferred to the next meeting. The tentative plan established was to resolve the topic in March.

4 CE1: Decoder-side motion vector derivation

4.1 Summary

JCTVC-D174 CE1: Summary Report of Decoder-Side Motion Vector Derivation [Yi-Jen Chiu, Haoping Yu, Yu-Wen Huang, Shun-ichi Sekiguchi]

This report was a summary of core experiment 1 (CE1) on Decoder-side Motion Vector Derivation (DMVD). There were four Subsets in CE1, candidate-based reference block prediction DMVD (Subset 1), template matching based DMVD (Subset 2), per-pixel optical-flow based DMVD (Subset 3), and refinement techniques based on transmitted MVs (Subset 4) as described in JCTVC-C501. The proposals were evaluated based on the common conditions in JCTVC-C500. The detailed results were reported by proponents, and each proposal had at least one cross-checker to examine the results.

4.2 Contributions

JCTVC-D329 CE1: Samsung's test for bi-directional optical flow [E. Alshina, A. Alshin, Woo-Jin Han (Samsung)]

This contribution related to CE1 Subtest 3. A coding gain of 1.9% for HE RA, and 4.8% for LC RA was reported. Roughly 12% and 100% increases in encoder and decoder runtimes for HE RA were reported. Roughly 11% and 150% increases in encoder and decoder complexity for LC RA were reported.

It was suggested that the concept presented in this contribution could be merged with concepts in other proposals to produce an improved design. It was not suggested that this proposal is sufficiently mature for adoption in its present form. Further study was encouraged (e.g., in an AHG).

JCTVC-D121 CE1:Cross-verification report of Samsung's Proposal by JVC KENWOOD [Motoharu Ueda, Satoru Sakazume]

Cross-check for JCTVC-D329.

JCTVC-D412 CE1: Cross-check result on Bi-directional optical flow of Samsung [Eunyong Son, Jiwook Jung, Sehoon Yea]

Cross-check for JCTVC-D329.

JCTVC-D120 CE1:Refinement motion compensation using DMVD with merge extension [M. Ueda (JVC KENWOOD)]

This contribution related to CE1 Subtest 4. A coding gain of 1.6% for HE RA was reported. Roughly 50% and 40% increases in encoder and decoder runtimes for HE RA were reported. No gain was shown in the LD case. The decoder complexity increase is primarily due to ME operation in the decoder. Further investigation and potential harmonization with other concepts was suggested (e.g., in AHG).

JCTVC-D340 CE1: Cross-verification of Kenwood's experimental results of refinement motion compensation using DMVD (JCTVC-D120) by Samsung [E. Alshina, W.-J. Han, A. Alshin (Samsung)]

Cross-check for JCTVC-D120.

JCTVC-D099 CE1: Report of implicit direct vector derivation [Yusuke Itani, Shun-ichi Sekiguchi (Mitsubishi)]

This contribution related to CE1 Subtest 1. A coding gain of 0.5% for HE RA was reported. A minor increase in encoder runtime, and 25% increase in decoder runtime were reported. No coding efficiency improvement was reported for the LD case. Further investigation and potential harmonization with other concepts was suggested (e.g., in AHG).

JCTVC-D168 CE1: Cross-check of DMVD results from Mitsubishi (JCTVC-D099) [Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)]

Cross-check for JCTVC-D099.

JCTVC-D295 CE1：Huawei report on TMDMVD and STDM in HM [Mingyuan Yang, Sixin Lin, Haoping Yu]

This contribution related to CE1 Subtests 1 and 2.

For Subtest 1, a coding gain of 2.0% for HE RA was reported. Roughly 70% and 6% increases in encoder and decoder runtimes were reported. If decoder template matching is added, an additional 0.3% coding gain was reportedly achieved, with higher complexity. It was suggested that some of the encoder complexity increase can be avoided. (It was noted that the complexity of the anchor can also be improved.)

For Subtest 2, a coding gain of 1.0% for HE LD was reported. Roughly 78% and 14% increases in encoder and decoder runtime were reported.

It was suggested that combination of this proposal with JCTVC-D167 may be feasible.

JCTVC-D169 CE1: Cross-check of DMVD results from Huawei (JCTVC-D295) [Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)]

Cross-check for JCTVC-D295.

JCTVC-D295 has two tools:

- Template matching based DMVD (TMDMVD) for GPB slices and
- Spatial-Temporal Direct Mode (STDM) for non-GPB slices.

As such, TM-DMVD is tested in both LD and RA cases, but STDM is tested only in RA cases in JCTVC-D295.

Both STDM and TMDMVD-plus-STDM are cross-checked in JCTVC-D169.

Common conditions were followed. The results are complete.

The BD BR results in JCTVC-D169 and JCTVC-D295 match completely. The encoding/decoding times differ slightly (as typically expected).

Initially, JCTVC-D295 did not contain encoder runtime data. Upon checking with Huawei, a supplementary excel file was provided by Huawei and the encoder runtime was comparable to the cross-checked data.

Often, the cross-checker reported a lower increase of encoder/decoder runtime.

The cross-checker studied the software source code very carefully. They compiled and ran the program.

No irregularity was observed.

JCTVC-D247 CE1: Cross Check with JCTVC-C501 (3.1.2) [Yue Yu, Krit Panusopone, Limin Wang] (missing prior, uploaded Thursday 20th, first day of meeting)

Partial cross-check for JCTVC-D295 (and JCTVC-C501 – subset 2).

Only the Low delay (HE and LC) cases were cross-checked for JCTVC-D295 in JCTVC-D247.

In JCTVC-D247, the labelling of results had a mis-alignment problem, e.g. Class B was labeled as Class A.

With the mis-alignment problem compensated, the BD BR data of JCTVC-D247 reportedly matched the corresponding result of JCTVC-D295. The encoder/decoder runtimes also matched.

The software was not carefully studied by the contributor of JCTVC-D247 – just compiled and run; however, since an additional cross-checker (JCTVC-D169) provided a more complete and very thorough analysis, this was not considered a serious problem.

No irregularity was observed.

JCTVC-D167 CE1: Report of self derivation of motion estimation in TMuC 0.9 [Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)]

This contribution related to CE1 Subtest 1. A coding gain 1.7% for HE RA was reported. Roughly 23% and 4% increases in encoder and decoder runtimes were reported.

For a 2nd variation with motion search added, a coding gain of 2.9% for HE RA was reported. Roughly 34% and 19% increases in encoder and decoder runtimes were reported.

The relatively minor increase of decoder complexity was noted, although there was some interest expressed in being able to carefully study the software for the proposal to check how realistic this is (e.g., the degree to which software optimization is a part of this measurement).

JCTVC-D098 Report of CE1 :Decoder-Side Motion Vector Derivation [Shun-ichi Sekiguchi, Yusuke Itani (Mitsubishi)] (missing prior, uploaded Tuesday 18th, before meeting)

Cross-check for JCTVC-D167 (JCTVC-C127).

JCTVC-D167 has 3 methods tested:

- 6-candidate,
- 6-candidate-plus-refinement,
- 9-candidate

The first two are cross-checked in JCTVC-D098. The third one is for info only, and not cross-checked.

In both JCTVC-D098 and JCTVC-D167, common conditions were followed. The results are complete.

The BD BR results in JCTVC-D098 and JCTVC-D167 match completely. The encoding/decoding time differs slightly, as expected in many cross-check situations, as different computers are used.

In general, the cross-checker in JCTVC-D098 showed lower increases in encoder/decoder runtime (e.g. 124% instead of 119%, 105% instead of 108%, 130% instead of 117%, 135% instead of 125%)

The cross-checker studied the software source code to some extent. They compiled the program themselves and ran the program.

No irregularity was observed.

JCTVC-D446 CE1: Cross-verification report for the part of JCTVC-D167 proposed by Intel [Motoharu Ueda] (late registration Monday 24th after start of meeting, uploaded Monday 24th, fifth day of meeting)

Cross-check for part of JCTVC-D167 (successful cross-check).

4.3 Discussion and Conclusions

O. Au was requested to coordinate collection of cross-verification summary information for JCTVC-D167 and JCTVC-D295, as checked in JCTVC-D098, JCTVC-D169, and JCTVC-D247. The information collected is recorded above.

There was some discussion of creating a unification proposal relating to JCTVC-D167, JCTVC-D295 and JCTVC-D098. The following contribution was then submitted.

JCTVC-D448 CE1 Subtest1: A joint proposal of candidate-based decoder-side motion vector derivation [Y.-J. Chiu, L.Xu, W. Zhang, H. Jiang (Intel), M. Yang, S. Lin, H. Yu (Huawei)] (late registration Tuesday 25th after start of meeting, uploaded Tuesday 25th, sixth day of meeting)

This contribution described a joint recommendation of the techniques of JCTVC-D167 and JCTVC-D295: a candidate-based Decoder-side Motion Vector Derivation (DMVD) technique to improve the coding efficiency relative to TMuC 0.9 reference software. The recommendation of the Candidate-based-DMVD (C-DMVD) had reportedly demonstrated an overall 2.0% BD BR improvement for the RA HE configuration under the common test conditions with 23% increase in encoding time and 5% increase in decoding time. A description about the normative syntax change about C-DMVD in the form of HEVC specification was included. Mitsubishi cross-checked the result and the estimate of the increase in encoding time was around 20% and the increase of decoding time was around 9%.

The range of per-sequence BD BR improvement was reported as 0.9-3.4%.

This proposal is only for the RA case.

It was remarked that the described scheme creates a dependency between the the parsing process and the reconstructed sample values of the previously-decoded reference pictures, and removing this dependency might reportedly degrade the performance by about 0.7%.

This is somewhat different than having a dependency on the motion vector values in the previously-decoded reference pictures. It is also different from having a dependency on the reconstructed sample values of the current picture (which could perhaps provide another 0.5% gain – e.g., see JCTVC-D295).

It was noted that the proposal seems to increase memory bandwidth for the motion compensation process by up to 9x relative to ordinary bi-prediction. Decoder bandwidth is a major concern in the design.

Due to concern about the effect of this proposal on the decoder memory bandwidth, it was concluded that further study was needed. Such further study was encouraged, to try to find an alternative approach with a considerable reduction in memory bandwidth.

It was suggested that limiting the size of the fetch area might be beneficial.

JCTVC-D450 Cross-check report on harmonized DMVD technique (JCTVC-D448) [Shun-ichi Sekiguchi, Kazuo Sugimoto(Mitsubishi)] (late registration Tuesday 25th after start of meeting, uploaded Thursday 27th, near the end of the meeting)

Cross-check of JCTVC-D448 (without reported difficulty).

5 CE2: Flexible motion partitioning

5.1 Summary

JCTVC-D229 CE2: Summary of Core Experiment 2 on Flexible Motion Partitioning [E. Francois (Technicolor), X. Zheng (Huawei&Hisilicon), P. Chen (Qualcomm)]

This document summarized the activity of CE2 related to Flexible Motion Partitioning. The description of the experiment can be found in JCTVC-C502r1. In this CE, three tools for motion partitioning had been studied: Asymmetric Motion Partitioning, Motion compensation with adaptable block shapes, and Geometry Motion Partitioning. An additional tool has also been evaluated: OBMC. Seven companies had been involved as proponent or cross-checker.

5.2 Contributions

JCTVC-D367 CE2: Asymmetric motion partition with overlapped block motion compensation [M.-S. Cheon, I.-K. Kim, L. Guo, P. Chen, M. Karczewicz]

For HE RA, 1.0% BR improvement, and 13% and 2% impact on encoder and decoder runtimes; for HE LD, 1.2% BR improvement, and 10% and -1% impact on encoder and decoder runtimes.

The AMP scheme was somewhat different than what had previously been implemented in the TMuC software.

AMP was only being used for CU sizes 16x16 and above (which was not described in the document).

A participant also asked about the encoder optimization algorithm for this proposal, which was apparently not described in the contribution.

JCTVC-D328 CE2: Cross-checking of Asymmetric motion partitioning with OBMC proposal from Samsung and Qualcomm [E. Francois, P. Bordes (Technicolor)]

Cross-check for JCTVC-D367.

JCTVC-D298 CE2: Cross-verification of AMP from Samsung [X. Zheng (HiSilicon), H. Yu (Huawei)]

Cross-check for JCTVC-D367.

JCTVC-D297 CE2: Huawei & HiSilicon report on Flexible Motion Partitioning [X. Zheng (HiSilicon), H. Yu (Huawei)]

One version of the proposal provided the following results:

For HE RA, 3.2% BR improvement, and 243% and 0% impact on encoder and decoder runtimes; for HE LD, 2.7% BR improvement, and 200% and -5% impact on encoder and decoder runtimes.

The test results were incomplete in the initial uploaded version of the contribution.

A 'faster' version achieved 3.0% and 3.4% BR savings on average for the RA and LD cases, and a 'diagonal-only' variation resulted in about 1.6% and 1.7% BR savings on average for the RA and LD cases.

JCTVC-D405 CE2: Cross-check results of Huawei & HiSilicon's proposal [J. Kim, J. Lee, H. Y. Kim]

Cross-check for JCTVC-D297.

JCTVC-D418 CE2: Cross-verification report for Huawei's proposal (JCTVC-D297) from Microsoft J. Xu (Microsoft) (late registration Tuesday 18th, uploaded Wednesday 26th, near the end of the meeting)

Cross-check for JCTVC-D297.

JCTVC-D230 CE2: Simplified Geometry Block Partitioning [E. Francois, P. Bordes (Technicolor), L. Guo, M. Karczewicz (Qualcomm)]

Version 1:

For HE RA, 2.8% BR improvement, and 90% and -3% impact on encoder and decoder runtimes; for HE LD, 3.0% BR improvement, and 90% and 1% impact on encoder and decoder runtimes.

Version 2 "Faster":

HE RA 1.9%, 30%, -2%; HE LD 2.2%, 34%, 0%.

JCTVC-D368 CE2: Overlapped Block Motion Compensation for Geometry Partition Block [L. Guo, P. Chen, M. Karczewicz (Qualcomm)]

For HE RA, 2.0% BR improvement, and 29% and 5% impact on encoder and decoder runtimes; for HE LD, 2.3% BR improvement, and 36% and 3% impact on encoder and decoder runtimes.

JCTVC-D427 CE2: Crosscheck of Qualcomm's proposal of JCTVC-D368 by MediaTek [Jicheng An, Xun Guo] (late registration Thursday 20th after start of meeting, uploaded Thursday 27th, near the end of the meeting)

Cross-check for JCTVC-D368. Uploaded very late.

JCTVC-D173 CE2-subset 4: Cross-check report of Technicolor's proposal on Geometry adaptive block partitioning Simplification from INRIA [Laurent Guillo, Ronan Boitard]

Cross-check for JCTVC-D368.

5.3 Discussion and Conclusions

The participants indicated a desire to work on a unified proposal (e.g., as a CE from this meeting).

6 CE3: Interpolation filtering for MC (luma)

6.1 Summary

JCTVC-D155 Summary of CE3: interpolation for MC (Luma) [T.Chujoh (CE coordinator)]

This contribution was a summary of CE3: interpolation for MC (Luma). Eleven companies had been registered in CE3 and seven proposed tools had been evaluated using the common conditions, with cross-verification of each.

6.2 Contributions

JCTVC-D056 CE3: Luma Interpolation using MOMS [H. Lakshman, H. Schwarz, D. Marpe, T. Wiegand]

JCTVC-D058 CE3: Verification of Nokia adaptive DCT-IF/DIF filters [Minhua Zhou]

JCTVC-D059 CE3: Verification of Samsung new 6-tap/8-tap DCT-IF filter [Minhua Zhou]

JCTVC-D076 CE3: Verification results of Nokia's Proposal(JCTVC-D323) [L. Guo, I. S. Chong, M. Karczewicz]

JCTVC-D090 CE3 : Results on Bi/Single MC interpolation filter [Kenji.Kondo, Teruhiko Suzuki]

JCTVC-D091 CE3: Verification of Samsung new 8-tap DCT-IF filter [Kenji Kondo, Teruhiko Suzuki]

JCTVC-D150 Response to CE3: Region-based adaptive interpolation filter [Shohei Matsuo, Yukihiro Bandoh, Seishi Takamura, Hirohisa Jozawa]

JCTVC-D154 CE3: Non-uniform tap length filtering [T.Chujoh, K.Kanou, T.Yamakage (Toshiba)]

JCTVC-D158 CE3: Verification of Sony's Bi/Single MC interpolation filter (JCTVC-D090) [T.Chujoh, K.Kano, T.Yamakage (Toshiba)]

JCTVC-D159 CE3: Verification of Samsung's new 12-tap DCT-IF (JCTVC-D344) [T.Chujoh, K.Kano, T.Yamakage (Toshiba)]

JCTVC-D160 CE3: Verification of Qualcomm's 12/8-tap interpolation filter (JCTVC-D376) [T.Chujoh, K.Kano, T.Yamakage (Toshiba)]

JCTVC-D161 CE3: Verification of Nokia's complexity analysis for DIF [Takeshi Chujoh, Kazuyo Kano, Tomoo Yamakage] (missing prior, uploaded Tuesday 18th, before meeting)

JCTVC-D179 CE3:Cross-check for NTT's proposal on Region-Based Adaptive Interpolation Filter (JCTVC-D150) [Tomonobu Yoshino, Sei Naito]

JCTVC-D288 CE3: Crosscheck of Qualcomm's one-pass SIFO filtering for low complexity coding by MediaTek [Xun Guo, Jicheng An]

JCTVC-D294 CE3 : Crosscheck of Qualcomm's 12/8 tap interpolation filter by MediaTek [Jicheng An, Xun Guo]

JCTVC-D322 CE3: On complexity calculation of low complexity anchor [K. Ugur (Nokia)]

JCTVC-D323 CE3: Results for luma interpolation filter tests by Nokia and Qualcomm [K. Ugur, J. Lainema, A. Hallapuro (Nokia), M. Karczewicz, I. S. Chong, L. Guo (Qualcomm)]

JCTVC-D327 CE3: Cross verification of MOMS interpolation filter [K. Ugur, J. Lainema (Nokia)]

JCTVC-D341 CE3: Cross-verification of Qualcomm's experimental results for Luma interpolation using SIFO6 by Samsung [E. Alshina, W.-J. Han, J. Chen (Samsung)]

JCTVC-D343 CE3: Cross-verification of Toshiba's experimental results for NTLF with DCTIF 12/8 by Samsung [E. Alshina, W.-J. Han, J. Chen (Samsung)]

JCTVC-D344 CE3: Experimental results of DCTIF by Samsung [E. Alshina, J. Chen, E. Alshin, N. Shlyakhov, W.-J. Han (Samsung)]

JCTVC-D372 CE3: Cross check of Toshiba's luma interpolation filter JCTVC-D154 [H. Lakshman]

JCTVC-D376 CE3: Qualcomm's proposal for luma interpolation filters [I. S. Chong, L. Guo, M. Karczewicz]

JCTVC-D414 CE3 : Cross-check report of Toshiba's Non-uniform tap length filter [Jiwook Jung, Eunyong Son, Sehoon Yea] (late registration Monday 17th, uploaded Monday 17th, before meeting)

JCTVC-D419 CE3: Verification of Qualcomm's and Nokia's switching 8 taps low bit-depth interpolation filter by Samsung Elena Alshina, Woo-Jin Han, Jianle Chen (late registration Tuesday 18th, uploaded Tuesday 18th, before meeting)

JCTVC-D423 CE3: Verification results of Samsung's 8 Tap DCTIF with 6 bits coefficients under Encoder Restriction by Qualcomm [L. Guo, I. Chong, M. Karczewicz (Qualcomm)] (late registration Thursday 20th after start of meeting, uploaded Thursday 20th, first day of meeting)

6.3 Discussion and Conclusions

The current design for LC used 6-tap DIF, and for HE used 12-tap DCTIF.

It was noted that for the LC configuration, the implementation of the DIF did not take into account some available symmetry in the operation of the filtering process.

For the HE case, several proposals reportedly showed both improved coding efficiency and reduced (or not increased) complexity.

It was remarked that it may be possible to combine some ideas from multiple proposals.

It was remarked that dynamic range (as well as memory bandwidth) may be more of an issue with longer filters.

It was noted that longer filters may increase subjective ringing/mosquito artifacts.

It was remarked that the JCTVC-D344 8x8 separable filter with 6 bit tap values seemed interesting, relative to the current HE case, and it could provide 4.4% improvement relative to DIF for the current LC case. A cross-check had been provided in JCTVC-D059.

It was remarked that using the JCTVC-D344 interpolation while prohibiting the encoder from using 1/4-sample increments simultaneously both vertically and horizontally could provide 2% gain relative to current DIF and complexity reduction relative to the current DIF.

Toshiba and Qualcomm proposals also provide special treatment of certain positions.

A participant remarked that, especially for hardware implementation, having the same consistently-applied filter regardless of positions is desirable.

Decision: Adopted the JCTVC-D344 8x8 separable filter with 6 bit tap values (for both HE and LC, without restrictions on MV values).

Further study was also planned to be conducted (e.g., in a CE).

7 CE4: Interpolation filtering for MC (chroma)

7.1 Summary

JCTVC-D345 Summary of CE4: interpolation for MC (Chroma) [E. Alshina (Samsung)]

This contribution was a summary of CE4: interpolation for MC (Chroma). Ten companies had been registered in CE4 and nine proposed tools had been evaluated on the common condition with cross-verification for each.

An additional modified PSNR measure was used in the CE to try to assess a combined impact on the three color components as a result of the different chroma interpolation filter methods.

Some tabulated results are shown below. The table entries average together the results of two different filters in cases where a contribution has different filters for HE and LC. It was remarked that the 4-tap filters in JCTVC-D057 and JCTVC-D347 are extremely similar to each other (the same if tap values are rounded to 6 bits). The boldface row in the table is explained below.

Proponent & Contribution	Y-BD-BR	U-BD-BR	V-BD-BR	YUV-BD-BR	Dec Time [%]	# taps
Cisco JCTVC-D223	0.6%	9.2%	10.3%	3.2%	98%	2 separable (not 1/8 sample)
Nokia JCTVC-D324 Variant 1	-0.1%	-1.5%	-1.7%	-0.6%	97%	6/2 separable
Nokia JCTVC-D324 Variant 2	-0.2%	-3.2%	-3.7%	-1.3%	98%	6/2 separable
Samsung JCTVC-D347 Variant 3: 4x4 separable 6 bits tap values	**-0.4%**	**-5.4%**	**-6.3%**	**-2.2%**	**98%**	**4 separable**
Sejong University, SK Telecom JCTVC-D271	-0.4%	-5.9%	-6.8%	-2.4%	106%	6/2 separable
HHI JCTVC-D057	-0.4%	-6.2%	-7.3%	-2.5%	114%	6/4 separable
Qualcomm JCTVC-D349	-0.4%	-4.7%	-5.2%	-1.9%	121%	6
Samsung JCTVC-D347 Variant 1: 6 taps 8 bits	-0.5%	-6.3%	-7.5%	-2.6%	105%	6 separable

7.2 Contributions

JCTVC-D057 CE4: Chroma interpolation using MOMS based FIR filters [H. Lakshman, H. Schwarz, D. Marpe, T. Wiegand]

JCTVC-D162 CE4: Verification of Samsung's 4-tap DCT-IF Chroma [T.Chujoh, K.Kano, T.Yamakage (Toshiba)]

Cross-check for JCTVC-D162. It was remarked that the runtimes did not match those in JCTVC-D162 – perhaps a 10% difference – perhaps due to different platforms/compilers and whether or not the output is written to a file. It was remarked that, generally, substantial variance has been observed in runtime measures.

JCTVC-D223 CE4: Interpolation filtering of chroma samples using two-stage averaging [A. Fuldseth, G. Bjøntegaard (Cisco)]

JCTVC-D271 CE4 : Chroma Interpolation Filtering using High Precision Filter [J.-P. Kim, D.-Y. Kim, Jeongyeon Lim, Yung-Lyul Lee]

JCTVC-D272 CE4 : Cross-check of Samsung's DCT-IF 6-tab chroma filtering [Jeong-Pil Kim, Dae-Yeon Kim, Heongyeon Lim, Yung-Lyul Lee]

JCTVC-D289 CE4: Crosscheck of Qualcomm's 1/8 pel accuracy high precision filter interpolation filter for chroma by MediaTek [Jicheng An, Xun Guo]

JCTVC-D318 CE4: Cross verification of high precision chroma interpolation filter [K. Ugur, J. Lainema (Nokia)]

JCTVC-D324 CE4: Results for chroma interpolation filter tests by Nokia [K. Ugur, J. Lainema (Nokia)]

JCTVC-D346 CE4: Cross-verification of HHI's experimental results for Chroma interpolation using MOMS by Samsung [E. Alshina, W.-J. Han, J. Chen (Samsung)]

JCTVC-D347 CE4: Experimental results of DCTIF application for Chroma MC by Samsung [J. Chen, E. Alshina, W.-J. Han (Samsung)]

JCTVC-D349 CE4: High Precision Filtering for Chroma [P. Chen, M. Karczewicz]

JCTVC-D351 CE4: Cross-check for Cisco's Proposal [P. Chen, M. Karczewicz]

JCTVC-D373 CE4: Cross check of Nokia's chroma interpolation filter JCTVC-D324 [H. Lakshman]

JCTVC-D415 CE4: Cross-check report of Nokia's Chroma interpolation filter [Jiwook Jung, Eunyong Son, Sehoon Yea (LG)] (late registration Monday 17th, uploaded Monday 17th, before meeting)

JCTVC-D420 Huawei & HiSilicon report on CE4: Experimental results of DCTIF application for Chroma MC by Samsung Lingzhi Liu, Yongbing Lin, Haoping Yu (late registration Tuesday 18th, uploaded Wednesday 19th, before meeting)

Cross-check for JCTVC-D162.

JCTVC-D422 CE4: Cross-verification of Samsung 4-tap DCT-IF chroma filter [K. Ugur (Nokia)] (late registration Thursday 20th after start of meeting, uploaded Thursday 20th, first day of meeting)

Cross-check for JCTVC-D162.

7.3 Discussion and Conclusions

Decision: Adopted JCTVC-D347 Variant 3: 4x4 separable with 6 bits tap values (both for HE and LC).

8 CE5: Low complexity entropy coding improvements

8.1 Summary

JCTVC-D364 CE5: Summary report of CE5 on LCEC [X. Wang (Qualcomm), A. Fuldseth (Cisco)]

This document summarized the activities in Core Experiment 5 on Low Complexity Entropy Coding (LCEC). A group of seven companies had registered for participation in CE5.

8.2 Contributions

JCTVC-D366 CE5: Improved intra prediction mode coding with LCEC [M. Karczewicz, X. Wang, W.-J. Chen (Qualcomm), A. Fuldseth (Cisco)]

In this report, coding results of an improved intra prediction mode coding scheme are reported. Results show that based on the CE test conditions, an average coding gain of 0.5% can be achieved.

Coding of intra prediction modes is modified for 4x4 blocks (17 modes), 16x16 and 32x32 blocks (34 modes). If the chosen intra prediction mode iDir is equal to the most probable mode mostProbMode, code number 0 is assigned to this mode. Otherwise the codeword number n is found for iDir using a mapping table. 2 different tables are used, one with a 1-bit code and one with a 2-bit code for the most probable mode. Which table is used depends whether intra prediction modes of its left and above neighboring blocks are same.

The modes of neighboring blocks are used anyway to derive the most probable mode, therefore implications on complexity etc. seem to be marginal.

Question: Were the tables trained with the test sequences? Training of tables was done using CABAC and previous software version

Decision: Minor change that gives some gain – no objection raised – recommendation to adopt.

JCTVC-D187 CE5: Cross-check results of Qualcomm and Cisco's proposal (JCTVC-C263) by ETRI [S.-C. Lim, H. Lee, H. Y. Kim (ETRI)]

Cross-check of JCTVC-263 – compiled source code and got identical results, confirmed that gains are consistent over sequences

JCTVC-D403 CE5: Cross-check of Qualcomm/Cisco's proposal on improved intra prediction mode coding in LCEC [Y. H. Tan, C. Yeo, Z. Li (I2R)]

Cross-check of JCTVC-263 – compiled source code and got identical results.

JCTVC-D381 CE5: Cross-check of Qualcomm's intra mode coding for LCEC by Sony [J. Xu, A. Tabatabai]

Cross-check of JCTVC-263 – results match, was not possible to check the computation time (different platform used)

JCTVC-D369 CE5: Efficient coefficient coding method for 16x16 and 32x32 transforms in LCEC mode [S. Lee, I.-K. Kim, W.-J. Han, J.-H. Park (Samsung)]

This contribution was Samsung's response to the Core Experiment 5 on the low complexity entropy coding improvements. In this contribution, a coefficient coding method for 16x16 and 32x32 transforms in LCEC mode, which has been proposed in JCTVC-C210, was presented. Tandberg, Ericsson, and Nokia's coefficient coding method, which is currently implemented in the HEVC Test Model, had reportedly been extended for the efficient coding of the coefficients from 16x16 and 32x32 transforms. A simplified version of the proposed method which does not require any additional variable-length code tables was also presented. Experimental results reportedly showed that the proposed method provides good coding gain in intra and random access configurations without noticeable complexity increments.

LCEC reportedly lacks an efficient method to code the coefficients from large transforms (designed for 8x8). The method using new tables for larger block sizes (described in JCTVC-C210) reportedly gives BD BR savings of 1.4%, 0.8%, and -0.3% in intra, random access, and low delay configurations, respectively. A new low-complexity method, where for run<=63, the existing method was tested. For larger runs, an escape code is used, and the remaining run is coded directly. Average BD BR savings were reported as 1.1%, 0.5%, and 0.2% in intra, random access, and low delay configurations, respectively. Also for 32x32 transform, at most 16x16 coefficients are encoded.

There are other contributions (JCTVC-D374, JCTVC-D261) that target at the penalty of LCEC due to the limited coding of large-block transform coefficients.

Conclusion: The simple method (not using different tables for larger blocks) seems to be sufficient. It is well understood that there is a problem (restricting larger blocks to 8x8 coefficients is sub-optimum). However there may be other solutions to this (see JCTVC-D374, JCTVC-D261). This should be further investigated in CE5.

JCTVC-D194 CE5: Cross-check of Samsung's proposal for LCEC improvements [Thomas Davies] (missing prior, uploaded Monday 17th, before meeting)

Results matched, but there was some discrepancy in encoding and decoding time (132% vs. 116% encoder, 105% vs. 101% decoder for the full method; simplified method 126% vs. 112% encoder, 104% vs. 99% decoder). Potentially the relation with RDOQ needs more investigation.

JCTVC-D370 CE5: Improved coding of inter prediction mode with LCEC [W.-J. Chen, X. Wang, M. Karczewicz (Qualcomm)]

This document reported CE 5 results on modified coding of inter prediction mode with low complexity entropy coding (LCEC). The average gain was 1.9% for random access configuration and 2% for low delay configuration.

According to this proposal, split flag, skip flag, merge flag and direct flag are grouped and coded together with a symbol Inter_Partition. Unary codes are used. When Inter_Partition is coded, it indicates that additional information about prediction modes will follow. Mapping between symbol and codeword index is adaptive and CU depth dependent. The adaptation scheme is the same as used for other syntax elements. When Inter_Partition is coded, additional code is sent to signal one of other prediction modes for the current CU, e.g. Inter_2Nx2N or Inter_NxN, etc. A fixed VLC table at each CU depth is used for this purpose. (This gives 1.8% for RA and 1.6% for LD)

In addition, a "counter-based adaptation" is proposed. After encoding of each symbol the counter for this symbol is increased. If the current symbol's counter is greater than the counter of the symbol with the codeword index smaller by one, the codeword indices of these symbols are swapped. The additional advantage of this method was reported as 0.4% BR saving for LD, 0.1% for RA.

The word length of the counter implementation is 8-bit and could overflow (although this does not happen with the current test set).

The process of counter-based adaptation would require precise normative description (the cross-checker points out that it is relatively simple in the software).

It was remarked that this relates to CE9 where the usage of modes is investigated.

One expert pointed out that this targets similar methods of adaptation of mode encoding as in the original TENTM proposal.

The encoding and decoding time were more or less unchanged.

Conclusion: inter_partition symbol and adaptation is useful improvement giving some gain in LCEC. Several experts expressed support.

Decision: Adopt (no objection raised). Regarding the relation to CE9, it had been reported before that the method works also without the merge flag, and the adaptation seems to be beneficial regardless of the specific modes. Regarding the counter-based adaptation: Further study was recommended.

It was remarked that JCTVC-D140 also suggests a method of counter-based adaptation.

It was noted that there may be some interaction between this proposal and other aspects that are evolving in the design – e.g., in relation to CE9.

JCTVC-D449 Cross-verification of Microsoft's method in JCTVC-D140 based CE9.3.1.t software [T.Lee, J.Chen(Samsung)] (late registration Tuesday 25th after start of meeting, uploaded Wednesday 26th, near the end of the meeting)

JCTVC-D131 CE5: Crosscheck of Qualcomm's Modified LCEC by MediaTek [Ching-Yeh Chen, Yu-Wen Huang]

(The person who was familiar with this cross-check in detail was not in the room when discussed.) Reportedly the software was studied and compiled and run independently. The company supported the proposal.

JCTVC-D319 CE5: Cross verification of Qualcomm's counter adaptation for LCEC tool [K. Ugur, J. Lainema (Nokia)]

This contribution only cross-checked the counter adaptation part in detail.

JCTVC-D374 CE5: Improved coefficient coding with LCEC [M. Karczewicz, X. Wang, W.-J. Chien (Qualcomm)]

Coding results of modifications of coefficient coding were reported. Results were available for both the cases of applying the proposed coefficient coding alone as well as applying it together with adaptive scan. In addition, the same idea was extended to the case of 16x16 coefficient coding, with results reported.

The current tables in the HM that map the {levelID, run} pair to code number are only used for inter blocks. New mappings to code numbers were introduced for blocks coded in intra mode. In addition, for an intra block the selection of the table is dependent both on the position k of the current nonzero coefficient and a parameter n, which is defined as zero if the absolute value of any of the coefficient levels coded so far (in the inverse scan order) is larger than 1. Otherwise, it is defined as the number of non-zero coded coefficients, clipped to 4.

The results reportedly show that when applying the proposed coefficient coding scheme alone, an average coding gain of 1.6% can be obtained with all intra configuration, an average of 0.6% gain with random access configuration and 0.1% with low delay configuration.

For intra, the scheme was used both with and without adaptive scan. In the case of adaptive scans, three scans are used: horizontal, vertical and zig-zag. The scan order for first few coefficients (up to 64) is adaptively adjusted based on previously coded coefficients (using a counter as described in the document JCTVC-C250). This reportedly gives 3.3% BR reduction in total for intra.

The proposed scheme was also extended to 16x16 coefficient coding, using a "zero level" (instead of escape as in JCTVC-D369) to encode longer run-lengths. The average coding gain can reportedly reach 5.2% with all intra configuration. A 2.2% coding gain was observed with random access configuration, and 2.3% gain with low delay configuration.

In a new version, the whole scheme was combined with an improved RDOQ method (giving roughly another 1% but unclear how it relates to the modifications, i.e. how it would perform without being combined).

Individual elements of the proposal were examined and discussed individually:

1. New mappings to code numbers for intra
2. Adaptive scanning
3. Method for encoding transform blocks >= 16x16
4. RDOQ modification (non normative)

JCTVC-D444 Cross-check on Qualcom's new RDOQ for LCEC [David Flynn, Thomas Davies] (late registration Monday 24th after start of meeting, uploaded Monday 24th, fifth day of meeting)

JCTVC-D064 CE5: Verification of Qualcomm's contribution on LCEC [Jie Zhao, Andrew Segall]

This contribution confirmed the results on combinations 1, 1+2 and 1-3, with encoding time not precisely measured due to usage of a computer cluster.

JCTVC-D228 Cross-check of Qualcomm's proposal for improved coefficient coding for LCEC [A. Fuldseth (Cisco)]

This contribution confirmed the results on combinations 1+2 and 1-3, reporting that the encoding time was increased to 103-109% (should be negligible for item 1 alone).

8.3 Discussion and Conclusions

Decision: Adopted the approach of 2 code tables for intra mode coding (selection depending on neighbor block modes) from JCTVC-D366 into HM.

Decision: Adopted inter_partition symbol and its adaptation from JCTVC-D370 into HM

Decision: Adopted code number mapping specific for intra coding from JCTVC-D374 into HM.

Decision: Adopted RDOQ modification from JCTVC-D374 (non normative).

Further study (e.g., in a CE) was encouraged on items 2 and 3 in JCTVC-D374.

General observation: Hardly any proposal in this category comes with text that specifies syntax, semantics, decoder operation and encoding in a way precise enough to be included in a high-quality specification of the WD/HM.

9 CE6: Intra prediction improvement

9.1 Summary

JCTVC-D259 CE6: Summary Report of Core Experiments for Intra Prediction [A. Tabatabai]

This contribution provides a summary of Core Experiment 6, Intra Prediction Improvements. From a total of 9 proposed CE subtests, 8 had been cross-checked with full match by at least one organization. For cross checking, the recommended test conditions of intra-only were used for both high compression efficiency and low complexity as defined in the document JCTVC-C506_r3.

Intra prediction improvement core experiments was divided into 4 categories

- CE6.a: Block Based Intra Prediction
- CE6.b: Line/Pixel based Intra Prediction
- CE6.c: Edge Based Intra Prediction
- CE6.d: Parallel Intra Coding

Visual investigation performed for CE6.c (edge-based)

Some of the methods have significant increase in encoder runtime (and also some increase of decoder)

A recent bug fix in CABAC (potentially wrong probability estimate) was not included in the CE results.

9.2 *CE6a Block based intra prediction*

JCTVC-D108 CE6 Subset A: Bidirectional intra prediction (JCTVC-C079) [Taichiro Shiodera, Akiyuki Tanizawa, Takeshi Chujoh, Tomoo Yamakage (Toshiba)]

This contribution presented the experimental results of Bidirectional Intra Prediction (BIP) for Core Experiment 6 (CE6) on intra prediction improvement. BIP was included in the CfP submission of JCTVC-A117 and was proposed in the contribution of JCTVC-C079 at the JCT-VC Guangzhou meeting.

In this document, experimental results in TMuC software version 0.9 under the common test conditions defined by CE6 were reported. For I slice only coding structure, the average BD BR gain was 2.0% on low complexity condition and 1.4% on high efficiency condition. Experimental results reportedly indicated that BIP can improve the coding efficiency for intra coding with minimum complexity increase.

BIP combines two unidirectional intra predictions results by a weighted sum according to the distance between the predicted pixel and the reference pixel(s) used for prediction. These unidirectional intra predictions are based on Unified Intra Prediction (UIP) integrated in current TMuC 0.9 software. The bidirectional modes are based on directions used in neighbored blocks and their counter-directions.

Encoding time 107/114% for HE/LC intra

Decoding time 106/110% for HE/LC intra

For 4x4 blocks, the gain by BIP + 17 UIP directions is reportedly higher than with 34 UIP directions (i.e. higher benefit of UIP modes)

JCTVC-D066 CE6: Verification of Toshiba's contribution on BIP [Andrew Segall, Jie Zhao]

JCTVC-D196 CE6: Cross verification of Toshiba bidirectional intra prediction [J. Lainema, K. Ugur (Nokia)]

JCTVC-D350 CE6.a: Chroma intra prediction by reconstructed luma samples [J. Chen, V. Seregin, S. Lee, W.-J. Han (Samsung), J. Kim, B. Jeon (LG)]

This document reported results of the "Chroma intra prediction by reconstructed luma samples" method proposed in document JCTVC-C206 within the context of CE6. In the proposed method, chroma samples are predicted from luma samples of same block by linear model relationship (line equation with slope and intercept found by least-squares solution). Compared to the TMuC0.9, the average BD BR gain is 1.4%, 6.3% and 5.2% for intra configuration, the average BD BR gain is 0.7%, 5.8% and 3.7% for random access configuration, respectively for Y, Cb and Cr components. The encoding/decoding measurement and operation number analysis reportedly prove that complexity of proposed intra prediction method is similar and even smaller to the existing method in HEVC or AVC.

The least squares solution is computed at the decoder from the boundary samples of neighboring blocks (LM mode).

Two modes are suggested: "LM5" with 5 modes (horizontal/vertical/DC/LM/DM) and "LM3" (DC/LM/DM). LM3 is claimed to be less encoding time than anchor, decoding time not changed.

It was claimed that the gain would be higher for 4:2:2 or 4:4:4 YUV due to having a higher number of chroma samples.

One expert raises the issue that luma and chroma cannot be processed in parallel.

The perceptual quality was not tested.

The actual bit rate reduction is more in the range of the luma (may be around 2% for intra).

JCTVC-D110 CE6 Subset A: Cross check report of Samsung's proposal (JCTVC-C206) from Toshiba [Akiyuki Tanizawa, Taichiro Shiodera (Toshiba)]

Confirms results for LM3

JCTVC-D145 CE6: Cross-verification report for Samsung's proposal from Microsoft [J. Xu (Microsoft)] (missing prior, uploaded Tuesday 18th, before meeting)

Confirms results for LM5

JCTVC-D398 CE6: Cross verification of Samsung chroma intra prediction [M. Coban]

JCTVC-D026 CE6.a: Santa Clara University and Hisilicon Report on Block Based Intra Prediction [Guichun Li, Lingzhi Liu, Nam Ling, Jianhua Zheng, Philipp Zhang]

The Intra Plane Mode and Intra Bilinear Mode were implemented in Unified Intra Prediction (UIP) based on the TMuC version 0.9. Simulations were performed on different combinations of Intra Modes and the results were analyzed.

Multiple Predictor Sets (MPS) method was used for PUs with MaxMode == 36 (size of 8x8, 16x16, and 32x32). 36 intra predictors were grouped into 4 sets, with 9 in each. Each mode was represented by a Group number and Index number.

Bilinear mode was not used. MPS with plane mode reportedly gives a little gain (0.2% and 0.4% for HE and LC cases).

A slight increase in encoder run time (102%) was reported.

JCTVC-D348 CE6.a: Cross-verification of intra prediction improvement from Santa Clara University and Hisilicon (JCTVC-D026) [J. Chen, J.-H. Min (Samsung)]

9.3 CE6b Line/pixel based intra prediction

JCTVC-D299 CE6.b Report on Short Distance Intra Prediction Method [X. Cao (Tsinghua), X. Peng (USTC), C. Lai (HiSilicon), Y. Wang (Tsinghua), Y. Lin (HiSilicon), J. Xu (Microsoft), L. Liu (HiSilicon), J. Zheng (HiSilicon), Y. He (Tsinghua), H. Yu (Huawei), F. Wu (Microsoft)]

This document reported experimental results of the short distance intra prediction (SDIP) scheme for core Experiment 6 on intra prediction improvement. SDIP was presented in JCTVC-C101 and JCTVC-C270. By dividing the NxN block into lines or non-square blocks, SDIP can reportedly reduce the energy of the prediction residuals by reducing the distance of predicted pixel and its reference pixels. When integrated into the TMuC 0.9 (HM) software, it reportedly shows 4.3% and 5.7% bit rate saving on average, under all intra high efficiency and low complexity conditions, respectively, with about 50% encoding time increase and no obvious decoding time increase.

A square block which is smaller than 32x32 is divided into several lines or non-square blocks with rectangular shape. In the block, pixels are predicted and reconstructed line by line or rectangle by rectangle. In contrast to previous contribution, UDI can be used within the small blocks. In case of pixel-wide partitions, the same mode is used for 4 adjacent partitions. Transform sizes are also adapted to the block sizes.

The numbers given above relate to a so-called "fast" configuration (encoding time increase is roughly 60% and 45% for HE and LC settings, respectively); decoding time increased by 5%

For LC, RDOQ is turned off in SDIP mode (comment: RDOQ of LCEC is anyway not performing well for intra).

SDIP is used for approximately 33% of the blocks on average.

The following comments were recorded in the discussion:

- This introduces substantial changes to block structures
- Adds new transform sizes as well (even though based on the same 1D separable bases) + scanning
- Not using RQT for SDIP signalling.

JCTVC-D124 CE6: Verification results of Huawei/ Hisilicon and Microsoft proposals [Jungsun Kim, Byeongmoon Jeon]

JCTVC-D191 CE6: Report and evaluation of new Combined Intra Prediction settings [Marta Mrak, Thomas Davies, David Flynn, Andrea Gabriellini]

This report presents various implementations of Combined Intra Prediction (CIP) in TMuC 0.9, in the context of CE6. The presented approach enables selection of CIP settings of different complexities. A selection of CIP settings was evaluated and the results were presented. The results reportedly show that without noticeable increase of complexity, compared to TMuC 0.9, the average BD BR gain for all intra coded sequences is 0.3% and 0.7% for the high-efficiency and low-complexity configurations, respectively. While the gain is reportedly negligible for lower resolutions, on higher resolutions it is reportedly larger - e.g. the average reported gain for Class A is 1.2% and 2.4% for the high-efficiency and low-complexity configurations, respectively. CIP implementation was discussed and parallelizable implementations were presented.

CIP – Combination of directional prediction and local mean prediction (average of decoded neighbor values); prediction is performed open loop. Predictor geometry is adapted based on the position in the block and on the prediction direction.

Usage of CIP can be restricted to certain block sizes (e.g. for low-complexity settings)

Results: "High complexity mode" 1.5/2.5% BR reduction with 75%/117% encoder runtime increase with HE/LC; for "Low complexity" 0.3/0.7% BR reduction with no/4% encoder runtime increase.

It is noticeable that decoder runtimes are slightly increased in all cases.

Sequential processing of pixels is necessary unlike other intra prediction methods, and there is some irregularity (switching of template geometry) at the pixel-level which may be an explanation.

JCTVC-D065 CE6: Verification of BBC's contribution on intra coding [Andrew Segall, Jie Zhao]

JCTVC-D204 CE6: Cross-check report on combined intra prediction [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda]

9.4 CE6c Edge based intra prediction

JCTVC-D279 CE6.c: Summary and Improvements of DCIM [E. Maani, A. Tabatabai, T. Yamamoto]

This contribution presented a summary of DCIM Core Experiment (CE) results, its enhancements, and visual quality evaluation. Moreover, the results of additional experiments that demonstrate when DCIM is used, the maximum number of Unified Intra (UI) directions can reportedly be safely reduced from 34 to 17 with a slight improvement of average coding efficiency. More precisely, these experiments reportedly show that using 17 Intra directions with DCIM performs, on average, 2.3% and 2.6% better than the HM anchors with 34 Intra directions.

Prediction direction is determined by applying a Sobel edge detection

Encoding time increase 8%/15% Decoding time increase 6%/19% with 2.3%/2.6% for the HE/LC configs.

Subjective evaluation did not unveil improvement/degradation when video shown, but improvements in some frames.

Approximately 60% of the blocks use the mode currently.

The edge orientation is determined from a boundary stripe that is 4 pixels wide.

JCTVC-D177 CE6.c: Cross-check report on Differential Coding of Intra Modes (DCIM) [Atsuro Ichigaya, Yasuko Sugito]

JCTVC-D205 CE6: Cross-check report on differential coding of intra mode [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda]

JCTVC-D218 CE6.c: cross verification of edge-based intra prediction [Virginie Drugeon]

9.5 CE6d Parallel intra coding

JCTVC-D074 CE6: Parallel intra coding [Jie Zhao, Andrew Segall]

In a previous contribution (JCTVC-B112) a concept of a parallel prediction unit (PPU) within the HEVC test model (HM) design was proposed. The goal of the parallel prediction unit is to define a group of pixels that are intra-coded, and where the intra-coding may be done in a parallel fashion. Parallelization is achieved by partitioning the intra-coded blocks into two sets. Blocks in the first set are predicted in parallel using available pixels outside PPU; blocks in the second set are also predicted in parallel using available pixels outside the PPU as well as pixels from the first set of blocks. The contributor implemented parallel intra coding into HM 0.9 and reported that the parallel intra coding results in negligible impact on coding efficiency. For all intra coding, approximately a .3% loss in coding efficiency when the PPU is 16x16. For random access and low delay configurations, between 0.0% and 0.1% loss in coding efficiency. For all cases, a PPU of 16x16 means that 4x4 blocks are processed in parallel.

Subdivision of block groups into 2 subsets in a checkerboard-like approach. When the first subset is decoded, the second subset can even be predicted from blocks below (non-causal). The second set is using weighted prediction.

BD rate loss roughly 0.3% for intra. Encoding time increase was observed (due to necessity of comparing different block configurations in tradeoff between parallelism and efficiency), but this was compensated avoided by further optimization.

The second subset requires more computation due to weighted prediction, which is however not noticeable in terms of decoding time.

Block structures not allowing regular checkerboard might affect the advantage of parallel processing, but this should have some lower limit.

JCTVC-D111 CE6 Subset D: Cross check report of Sharp's proposal (JCTVC-B112) from Toshiba [A. Tanizawa, T. Shiodera (Toshiba)]

9.6 Discussion and Conclusions

Most of the proposals added complexity with some benefit on compression performance

Complexity in intra prediction can not only be judged by encoder/decoder runtime, but rather must take into account number of pixel operations, pipelining in sequential processing etc. – a number of these issues have been identified and proponents are asked to address them.

The potential mutual benefit resulting from addition of compressions gains is not clear – it would be desirable to test combinations.

In terms of decoder complexity judgement, worst-case scenarios (e.g. extreme frequent usage of more complex modes) must be considered.

Visual evaluation could be necessary.

Continuation of CE was encouraged – major goals of this CE should be to investigate:

- combining different approaches of intra prediction rather than running in parallel
- investigating the complexity

Note: A method for improved intra prediction of chroma was adopted (see JCTVC-D255/JCTVC-D278).

10 CE7: Alternative transforms

10.1 Summary

JCTVC-D042 CE7: Alternative Transforms - Summary Report [R. Cohen, C. Yeo, R. Joshi]

This document provided a summary and table of documents related to Core Experiment 7 (CE7) on Alternative Transforms. The purpose of Core Experiment 7 (CE7) was to investigate the performance of transforms other than the conventional integer DCT-like transform currently in HM (TMuC 0.9).

The types of proposed transforms and methods generally fall into one or more of the following categories:

1) MDDT Simplification
- Separable DCT/KLT
- Separable DCT/DST
- Mode-mapping (Intra prediction direction mapped to transform mode)
- Coefficient ordering/scanning
- Use of symmetry to reduce the number of transforms

2) ROT Improvements

10.2 MDDT simplification

JCTVC-D107 (m18858) CE7: Experimental results for one-dimensional directional unified transform (JCTVC-C080) [Akiyuki Tanizawa, Jun Yamaguchi, Taichiro Shiodera, Takeshi Chujoh, Tomoo Yamakage (Toshiba)]

This contribution presented experimental results of the use of a 1 Dimensional Directional Unified Transform (1DDUT) for Core Experiment 7 (Alternative transforms in HEVC). 1DDUT is a spatial transform scheme for intra coding. 1DDUT has only two 1-D transform matrices, which are one similar to a Discrete Cosine Transform (DCT) and the directional transform based on Karhunen-Loeve Transform (KLT). 1DDUT was proposed in the contribution of JCTVC-B042 at the JCT-VC Geneva meeting and JCTVC-C080 at the JCT-VC Guangzhou meeting.

In this document, experimental results in TMuC software version 0.9 on both high efficiency conditions and low complexity conditions based on the common test conditions for both I slice only coding structure and the random access coding structure defined by CE7 were reported. For I slice only coding structure, the BD-Bit rate gain compared with the anchor was reported as 2.2% on average, and for the random access coding structure, the BD-Bit rate gain was reported as 0.8% on average. Experimental results reportedly indicated that 1DDUT can improve the coding efficiency for intra coding with minimum complexity increase.

- DCT-like transform implementation is different than in HM
- Using 8 fixed scans for the directional transform
- 6 different quantization matrices for each transform size
- In combined prop. JCTVC-D392

JCTVC-D032 (m18775) CE 7: Cross-Check for Toshiba's proposal on 1-D Directional Unified Transform by Samsung [A. Saxena, F. C. Fernandes (Samsung)]

JCTVC-D264 (m19028) CE7: A crosscheck of Toshiba's proposal (JCTVC-D107) by Qualcomm [R. Joshi, P. Chen]

JCTVC-D046 (m18793) CE7: Mode-Dependent Transforms for Block-based Intra Coding from Institute for Infocomm Research [C. Yeo, Y. H. Tan, Z. Li, S. Rahardja (I2R)]

To simplify the operation of Mode Dependent Directional Transform (MDDT), a Mode-Dependent Fast Separable KLT for Block-based Intra Coding was previously introduced that requires two transform matrices: one like a DCT and one similar to a DST (Odd Type-3 DST). The 4x4 DST reportedly also has a structure that can be exploited to reduce the operation count of the transform operation. This contribution provided test results for CE7. Experimental results reportedly showed that the proposed technique matches the performance of using trained KLTs even though the approach requires no training, and has lower operation count and storage costs.

- In combined prop. JCTVC-D392
- Currently only 4x4 and 8x8 sizes
- For 8x8, matrix multiplication (no fast alg.)
- Only one scan
- 6 different quantization matrices for each transform size (claimed that it could be done by scaling)
- DCT not same kernel as in HM

JCTVC-D104 (m18855) CE7: Cross check report of I2R's proposal (JCTVC-D046) from Toshiba [A. Tanizawa, J. Yamaguchi (Toshiba)]

JCTVC-D306 (m19072) CE7: Crosscheck of I2R's proposal by Huawei [H. Yang, J. Zhou]

JCTVC-D353 (m19121) CE7: Cross-verification of I2R's experimental results of low complexity MDDT by Samsung [E. Alshina, W.-J. Han, A. Saxena (Samsung)]

Confirmed results; mentioned that for 8x8, the transform is implemented by matrix multiplication.

JCTVC-D033 (m18776) CE7: Mode-dependent DCT/DST for intra prediction in video coding [Ankur Saxena, Felix C. Fernandes]

It was previously reported that following intra prediction, the optimal transform is a Discrete Sine Transform (DST) with performance close to KLT, along the direction of prediction. In this contribution, the proponent used a transform like a Discrete Cosine Transform (DCT) or DST (separably along the vertical or horizontal directions) based on the intra prediction direction. The proposed DCT/DST transform scheme does not require any additional signaling information or Rate-Distortion search during encoding, and works in a single-pass. No training was required to derive the transform and the scheme requires the storage of only one DST matrix in addition to the conventional DCT-like transform at each block size. The conventional quantization tables for TMuC 0.9 are retained and no changes had been made to the scanning order. Experimental results were provided with TMuC 0.9 as anchor for the test conditions as stipulated in Core Experiment 7, and average BD Rate gains of 1.3%, 2.1%, 0.6% and 0.7% were respectively reported for Intra High Efficiency, Intra Low Complexity, Random Access High Efficiency and Random Access Low Complexity settings.

DST and DCT (once with kernel from HM block sizes 4x4 and 8x8, once with matrix multiplication block sizes up to 32x32)

6 quantization and inverse quantization matrices each were used.

No fast DST was used, and usage would require 3 additional quantization matrices.

For the case of only 4x4 and 8x8 transforms, BR reduction was reportedly 1.2%/1.9% for intra HE/LC cases, with encoder runtime increase to 104%/97%, decoder 102%/99%. Reported by cross-checkers, the runtimes are higher up to 110% also for LC case, and the proponent agrees that the numbers reported may not be reliable.

JCTVC-D031 (m18774) CE7: Cross-check for Samsung's Proposal on Jointly Optimal Intra Prediction and Adaptive Primary Transform by BBC [Ying Weng, Thomas Davies (BBC)]

JCTVC-D088 (m18838) CE7: Cross-check for Samsung's Proposal on Mode-dependent DCT/DST for intra prediction in video coding by NHK [Yasuko Sugito, Atsuro Ichigaya]

JCTVC-D105 (m18856) CE7: Cross check report of Samsung's proposal on mode-dependent DCT/DST (JCTVC-D033) from Toshiba [Akiyuki Tanizawa, Jun Yamaguchi (Toshiba)]

JCTVC-D399 (m19178) CE7: Mode dependent intra residual coding analysis [P. Chen, R. Joshi, Y. Zheng, M. Coban, M. Karczewicz]

In this contribution, several different methods of mode dependent intra residual coding are compared. They are mode dependent fix scan, adaptive switch scan and adaptive switch KLT+scan. The trade off between coding efficiency and complexity was discussed in the contribution.

- In combined prop. JCTVC-D392
- Three configs: Mode-dependent fixed scan, adaptive switch scan, adaptive switch KLT and scan
- Typically three scan orders: zig-zag, horizontal, vertical
- DCT implementation implemented by matrix multiplication
- Six quantization tables (one per QP) per block size
- Only fixed scan is used in joint proposal

JCTVC-D078 (m18828) CE7: Cross-check of Qualcomm's proposal by Institute for Infocomm Research [C. Yeo, Y. H. Tan, Z. Li (I2R)]

JCTVC-D307 (m19073) CE7: Cross-checking of MDDT results from Qualcomm [J. Song, H. Yang] (initial version rejected as a placeholder upload)

JCTVC-D354 (m19122) CE7: Cross-verification of Qualcomm's MDDT [E. Alshina, V. Seregin, W.-J. Han (Samsung)]

JCTVC-D392 (m19171) CE7: Mode dependent intra residual coding - A joint proposal based on several proposals from CE7 [R. Joshi, P. Chen, M. Karczewicz, A. Tanizawa, J. Yamaguchi, C. Yeo, Y. Tan, H. Yang, H. Yu]

This proposal suggests, for intra predicted blocks, for the prediction residual to be first transformed and then for the quantized transform coefficients to be entropy coded. By selecting transform and scan order based on intra prediction modes, higher coding efficiency is reporteedly achieved with small complexity increase.

2 transforms (pseudo DCT and DST) used, each for 4x4, 8x8, 16x16, implemented as matrix multiplications.

HE: 3 scans (zig-zag, horizontal, vertical) – horizontal and vertical are transposed versions

LC: adaptive scans (as from JCTVC-D304)

6 matrices (which are scalable versions of each other i.e. only one would need to be stored) per block size – different from HM quantization matrix.

2.1% BR reduction / 106% encoder time/ 105% decoder time for HE intra; 2.6% / 116% /114% for LC intra.

Another report is given about a VLC modification which increases the gain to 3% for LC intra.

JCTVC-D407 Verification of mode dependent intra residual coding [Seungwook Park, Jaehyun Lim, Byeongmoon Jeon] (missing prior, uploaded Thursday 20th, first day of meeting)

- Cross-check of JCTVC-D392

JCTVC-D304 (m19070) CE7: Simplified MDDT scheme using symmetry-based scanning orders [H. Yang, J. Zhou, H. Yu]

A SMDDT (Simplified MDDT) scheme was proposed in this document. It comprises two parts, ST (Simplified Transform) and SSO (Symmetry-based Scanning Order). In the SMDDT-ST, the combination of DCT and DST is used. In the SMDDT-SSO, 2 additional scanning orders as well as the existing zig-zag scanning order are used. The BD BR reduction of the proposed SMDDT scheme is 2.0% in the Intra HE case and 2.9% in the Intra LC case.

- In combined prop. JCTVC-D392
- Symmetric scanning orders (3 different, i.e. zig-zag and two more orders) are used, also in the joint proposal
- Swapping of horizontal/vertical memory position is used in implementation

JCTVC-D284 (m19049) CE7: Mode-dependent transform, residual reordering and coefficient scanning for intra prediction residue [Xin Zhao, Li Zhang, Siwei Ma, Wen Gao]

- Not in combined prop.

JCTVC-D290 (m19056) CE7: Crosscheck of PKU's proposal JCTVC-D284 by MediaTek [Xun Guo, Mei Guo]

In this contribution, the results from Peking Univ. for Core Experiment 7 (CE7) on Alternative Transforms were provided, with both tool description and simulation results. Simulation results were obtained under the test conditions defined in CE7, and the detailed rate-distortion measurements using BD BR values were provided in accompanying spreadsheets.

- Different re-ordering used for each prediction mode

- Integer transform is approximation of DST for 4x4, special transform for 8x8 ("something between DCT and DST"), precision 19/27 bits for the 4x4 and 8x8 cases forward transform, 64 bit precision for inverse transform
- Fast implementation of 4x4 case
- For 8x8 case, 6 quantization matrices are used (4x4 is orthonomal, therefore no quantization matrix is necessary)
- 6 different scanning methods
- BR saving 2%/2.5% for Intra HE/LC, encoder runtime 104%/106%, decoder runtime 104%/103% (in the decoder case, the cross-checker reports higher runtimes.

10.3 ROT improvements

JCTVC-D357 (m19125) CE7: Experimental results of fast ROT by Samsung [E. Alshina, A. Alshin, F.-C. Fernandes, Y. Piao, W.-J. Han (Samsung)]

This contribution provides simulation results when Rotational transform (ROT) is enabled in TMuC 0.9 against the TMuC 0.9 anchor results. In Intra-Only test case, about 2% (HE) / 3% (LC) gain was reportedly provided by ROT. In Random-Access test scenario ROT, gain is over 1% on average. No additional changes (like scan modification, for example) typically improving alternative transform performance were reportedly applied in this test.

Number of rotation matrices to be stored – horizontal/vertical 4 rotation variants for 4x4 and 8x8 each.

Integer rounding is applied, but in a manner such that orthogonality may be lost.

Implementation of ROT by matrix multiplication, due to sparsity of the set of coefficients on which the transform is applied, is claimed to require a lower number of operations than with an alternative (e.g. DST) transform. A lifting implementation was (verbally) reported to exist.

BR reduction 1.9%/2.9% in HE/LC intra only.

With "fast" algorithm, encoder runtime roughly 160%/200%; decoder runtime 97%/105%.

Restricted ROT with only best UDI mode: BR reduction 1.1%/1.9%, encoder roughly 120%.

Note: Loss of performance in chroma components.

JCTVC-D030 (m18773) CE7: Cross-verification of Samsung's (JCTVC-D357) Fast Rotational Transform [R. Cohen, A. Vetro, H. Sun (Mitsubishi)]

JCTVC-D409 (m19201) CE7: A crosscheck of Samsung’s fast ROT proposal (JCTVC-D357) by Qualcomm [P. Chen, R. Joshi]

10.4 Discussion and Conclusions

All proposals increase complexity to some extent

- Adding additional transform bases (DST and/or non-TM DCT)
- Matrix multiplication (no fast algorithms tested in most cases)
- Additional quantization matrices
- Additional scan orders

Rather than investigating runtimes, for cases of transforms, paper analysis of complexity would be desirable (or separate recording of runtime for the transform/quantization/scanning parts).

From the results shown, it is not clear yet whether all the complexity-increasing building blocks are necessary, or how much benefit would remain if some of these were removed.

It would be desirable to not use multiple transforms, or to restrict the number of block sizes for additional transforms to as few as possible.

It will be necessary to look into combination of improved intra prediction vs. simple transforms

Further study in CE – one major goal of CE's should be to investigate the additional complexity (not only by runtime measurements, which can be unreliable and can swamp out the effect of a tested technical design element with side-effects and the processing for other components) vs. compression benefit.

11 CE8: In-loop filtering

11.1 Summary

JCTVC-D085 Summary of Core Experiment 8 on In-Loop filtering [T. Yamakage (Toshiba), K. Chono (NEC), Y.W. Huang (MediaTek), M. Narroschke (Panasonic), I.S. Chong (Qualcomm)]

This contribution was a summary of core experiment 8 (CE8) on In-Loop filtering. There were three Subsets in CE8 as described in JCTVC-C508: Deblocking/debanding filters (Subset 1), Wiener-based in-loop filters (Subset 2) and Image clipping and offset (Subset 3).

11.2 Contributions

11.2.1 Subset 1: Deblocking and debanding

JCTVC-D137 CE8, Subset 1: Report of Content-Adaptive Deblocking [Z. Shi (USTC), Z. Xiong (USTC), X. Sun (Microsoft), J. Xu (Microsoft)]

JCTVC-D332 CE8 subset 1: Cross-verification result of Microsoft proposal by SKKU/SKT [Jungyoup Yang, Kwanghyun Won, Heechul Yang, Byeungwoo Jeon, Jeongyeon Lim]

Cross-check of JCTVC-D137.

JCTVC-D043 CE8: Conditional joint deblocking-debanding filter [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda (NEC)]

JCTVC-D144 CE8, Subset 1: Cross-verification report for NEC's conditional joint deblocking-debanding filter [Z. Shi (USTC), J. Xu (Microsoft)] (missing prior, uploaded Tuesday 18th, before meeting)

Cross-check of JCTVC-D043.

JCTVC-D163 CE8 Subtest1: Improved Deblocking Filter [Jicheng An, Xun Guo, Qian Huang, Yu-Wen Huang, Shawmin Lei]

JCTVC-D379 CE8 Subset1: Cross verification of Mediatek's deblocking filter by Ericsson [K. Andersson, A. Norkin, R. Sjöberg (Ericsson)]

Cross-check of JCTVC-D163.

JCTVC-D203 CE8 Subset1: Verification results of MediaTek's Proposal JCTVC-D163 [T. Yamakage (Toshiba)]

Cross-check of JCTVC-D163.

JCTVC-D334 CE8 subset 1: Results of intra deblocking filter testing by SKKU/SKT (JCTVC-C130) [Jungyoup Yang, Kwanghyun Won, Heechul Yang, Byeungwoo Jeon, Jeongyeon Lim]

JCTVC-D206 CE8: Cross-check report on SKKU/SKT deblocking filter [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda]

Cross-check of JCTVC-D334.

11.2.2 Subset 2: Wiener-based in-loop filters

JCTVC-D119 CE8 Subset2: A Joint Proposal on Improving the Adaptive Loop Filter in TMuC0.9 by MediaTek, Qualcomm, and Toshiba [C.-Y. Chen, C.-M. Fu, C.-Y. Tsai, Y.-W. Huang, S. Lei, M. Karczewicz, I. S. Chong, T. Yamakage, T. Chujoh, T. Watanabe]

New joint proposal by three of the (five) companies that participated in the CE (MediaTek, Qualcomm, and Toshiba).

For Subset 2, JCTVC-D119 was a new proposal from MediaTek, Qualcomm, and Toshiba. It differs from what was planned to be tested in this CE.

A participant remarked that this contribution includes a combination of different techniques that would be desirable to assess individually.

It was remarked that the chroma filtering should be investigated.

It was noted that although complexity reduction was a goal of the work, the worst case complexity is not reduced by the proposals.

It was noted that JCTVC-D119 proposes an ability for the encoder to add an offset as well as to apply filtering.

The adaptive offset method of JCTVC-D122 was integrated. However it was not operated in series with ALF, but rather was made switchable.

An additional hierarchy "filter unit" (FU) is introduced (always rectangular) – this could be in conflict with the case of multiple (non-rectangular) slices.

Elements of the proposed design were as follows:

- "Filter unit" (at least as large as an LCU, based on equal size blocks – could hypothetically be adaptive block size instead) definition – for each filter unit, can switch between three techniques
    - A reduced-complexity "pixel adaptation" similar to the current ALF operation, which chooses between up to 4 filters (rather than the current HM's 16) on a sample-by-sample basis, based on a modified (reduced-size) window decision that classifies samples into "groups" and applies the selected filters, each of which has one of the following characteristics:
        - 3x3 square with offset (new)
        - 5x5 square with offset (new)
        - 7x7 diamond with offset (as in current design)
        - 9x9 diamond with offset (as in current design)

        - no filter (as in current software)
    - A (new) "single filter" technique applied using a "time delay" filter, with two modes:
        - using coefficients from a previous picture (inter-picture prediction)
        - using transmitted coefficients
    - A (new) "adaptive offset" technique.
    - No filtering (on/off at both FU level and, if on at FU level, also sent at CU level)
- Reducing encoding passes from 16 to 1 (new).

    NOTE: Statistics are collected during the DF pass, then decisions are made, and one pass is performed for application of the ALF.

- Decoding non-normative (new) optimization savings (and perhaps some small syntax change) for recognizing when some processing can be avoided.

In the current design, there is no FU level – the filter is controlled at the CU level.

It was remarked that there is an issue in regard to applying the FU concept to slice-structured coding that would need to be resolved.

In JCTVC-D122, the "adaptive offset" technique could be used in addition to another filter instead of as an alternative as proposed in this contribution. This provides more reported gain, but adds extra processing.

Overall results were reported as follows: HE AI 0.1% worse, HE RA 0.4% better, HD LD 1.9% better in BD rate average. Decoding time reduced by 15%, encoding time approximately unchanged.

It was remarked that the number of encoding passes (and ALF overall) does not affect our total software simulation runtimes by much (although it would be a serious problem for implementations).

The presenter indicated that the one-pass encoding would cause a loss of fidelity by about 1%, if the other aspects were not included.

It was noted that non-normative configuration changes will be made to the test conditions, which could affect signal propagation fidelity in the LD predictive case.

The presenter asserted that the changes proposed would not conflict with those of the other proposals in the CE.

It was remarked that there is a relationship between the deblocking filter behavior and ALF behavior.

It was remarked that the subjective gain from ALF is much more substantial than the objective gain.

It was remarked that this proposes an increase in the complexity of the ALF design.

A participant asked what the impact would be of just using LCU signaling instead of introducing an additional FU layer. A proponent indicated that this would probably increase the amount of overhead to an unacceptable degree.

Since there are several distinct modifications proposed here, some of which seem to substantially increase ALF complexity, and since there are other proposals to consider that are closely related, further study would be needed to determine the appropriate action in regard to this proposal.

It was suggested (despite the reported 1% loss) that it would be nice to enable a way to configure the software to not use the current highly-multipass (16 pass) encoder behavior (while retaining the current behavior when configured for multi-pass). It may also be nice to be able to configure a multi-pass usage between the extremes of single-pass and 16 pass.

Decision: This was agreed. The software coordinator is generally delegated with the ability to decide when additional similar sorts of (non-normative) configurability are desirable.

JCTVC-D216 CE8: Cross-check results of the adaptive loop filter of MediaTek, Qualcomm and Toshiba [Semih Esenlik, Matthias Narroschke]

Cross-check of JCTVC-D119.

JCTVC-D114 CE8: Cross-check result of MQT adaptive loop filter [Tomohiro Ikai]

Cross-check of JCTVC-D119.

JCTVC-D170 CE8: Cross-check of MQT_ALF results from MediaTek, Qualcomm and Toshiba (JCTVC-D119) [Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)]

Cross-check of JCTVC-D119.

JCTVC-D115 CE8: DF-combined adaptive loop filter [Tomohiro Ikai, T. Yamazaki (Sharp)]

This contribution was a CE8 subtest 2 (Wiener-based in-loop filters) proposal.

This proposes a two-input filter, where one input is the output of the DF and the other is the pre-DF reconstruction.

The proposed method does not use sample-by-sample adaptation of the filter. It was remarked that such adaptation could be used and would provide some gain if used – perhaps somewhat more than 1%. (And a similar amount of gain would be lost if the adaptation were removed in the current design.)

The spatial extent of the proposed filtering supports diamond kernels of shape 7x7, 9x9, and 11x11.

It was remarked that adding 11x11 to the current design would provide an improvement, but that this had not been done for reasons of complexity.

It was remarked that this proposal tries to align luma and chroma processing elements. In our current reference configuration, chroma uses square filters while luma uses diamond ones.

The proposed technique proposes the ability to process the two inputs in parallel.

The experimental results for HE reportedly show 0.2%, 0.2%, and 0.7% BR reduction IO, RA, and LD. The decoding time ratio is 85% and the encoding runtime ratio is somewhat reduced. Additional experimental results show the DF-combined improvement, which is the bdrate difference between the proposal's two input result and a similar design (not the current ALF) using one input is 0.9%, 0.7%, 0.7% in IO, RA, and LD respectively.

Basically three aspects:

- Not using sample-by-sample adaptivity,
- Using two inputs rather than one (requires an extra frame store and multipass in encoder side, raising similar issues as for the JCTVC-D217 proposal),
- Including a larger-extent filter.

A participant remarked that subjective viewing results from viewing conducted for TE10 at the Guangzhou meeting demonstrated significant visual subjective improvement from the sample-by-sample adaptivity aspect of the current ALF (based on comparison between a Toshiba proposal without that adaptivity vs. QCALF and a Panasonic proposal).

In a sense, this approach can be roughly interpreted as a special case of the JCTVC-D217 three-input approach.

Further study was encouraged.

JCTVC-D215 CE8: Cross-check results of the DF-combined adaptive loop filter of Sharp [Matthias Narroschke, Semih Esenlik]

Cross-check of JCTVC-D115.

JCTVC-D211 CE8 Subset2: Verification results of Sharp's Proposal JCTVC-D115 [T. Yamakage (Toshiba)]

Cross-check of JCTVC-D115.

JCTVC-D217 CE 8: Results for adaptive loop filter using prediction and residual (3-Input-ALF) [S. Esenlik, M. Narroschke, T. Wedi (Panasonic)]

This contribution presented results of the Adaptive loop filter using both the prediction and residual (3-Input-ALF). An average Y-BD BR gain of 0.9% for AI HE, 0.8% for RA HE, and 0.4% for LD HE, compared to the official anchors can reportedly be achieved.

The proposal produces an output that is a weighted combination of:

- The DF output with spatial filtering and offset (N bits per sample),
- Prediction signal (N bits per sample),
- Residual difference signal (N +1 bits per sample).

The decoder (if it wants to use this feature) would need additional line buffers to store the extra signals.

The encoder may need multipass operation (for reference frames) with full frame stores for these extra signals.

At the CU level, signaling specifies whether to use the weighted combination or just the output of the DF (as in the current HM design).

The same weighting values are applied for all regions of the picture for which the weighting is enabled.

It was noted that one example set of values for this weighted combination would entirely disable the DF.

In (informal) testing done at the last meeting, it was reported that there was no (significant) visual degradation observed in any cases, and there seemed to be some improvement for one sequence.

It was remarked that other DF and ALF improvements might obviate the need for the three inputs.

Further study was encouraged.

JCTVC-D237 CE8 Subset2: Verification results of Panasonic's Proposal JCTVC-D217 [T. Yamakage (Toshiba), I.S. Chong (Qualcomm), Y.W. Huang (MediaTek)]

Cross-check of JCTVC-D217. The software was examined and determined to be consistent with the proposed technique and to be a straightforward implementation of the described scheme.

11.2.3 Subset 3: Image clipping and offset

JCTVC-D122 CE8 Subtest3: Picture Quadtree Adaptive Offset [Chih-Ming Fu, Ching-Yeh Chen, Yu-Wen Huang, Shawmin Lei (MediaTek)]

This contribution described a proposal using an adaptive offset (AO). The proposed picture quadtree adaptive offset (PQAO) uses local adaptation to increase coding efficiency. Each picture is proposed to be divided into multi-level quadtree partitions, and the samples in each leaf partition are affected by a band offset (BO) or edge offset (EO).

Both BO and EO classify samples of a partition into groups, and one offset is derived for each group.

The proposal adds another processing stage between the deblocking/debanding filter and the ALF (assuming both of these are active). This additional stage uses its own additional quadtree segmentation map.

For the "band offset", the "band" is a range of sample values, and the five MSBs are an index to determine the value of the offset, so that the offset may be different for each of 32 segments of the range from 0 to 255.

For the "edge offset", each sample is compared to the values of its neighbors to categorize each sample into one of 5 or 7 categories, and each category has an offset value.

When compared with the JCTVC-C500 anchor, PQAO reportedly achieves 1.5% and 2.2% bit rate reductions for HE-RA and HE-LD, respectively. For HE, the encoding time is increased by about 1%, and the decoding time is increased by about 2%.

For LC comparisons, the runtime increase for the decoder was more substantial.

Subjective testing was done in Guangzhou, with no significant difference observed.

The processing is parallelizable – output samples do not become input to the processing of other samples.

The processing crosses CU boundaries, so if processing CU-by-CU, it is necessary to delay the processing until the CU to the right and the CU below the current CU is available.

It was noted that ALF also has some offset processing in it.

It was remarked by several participants that ALF has some similar types of processing in it that have not been fully analyzed, and it would be beneficial to try to find a way to find gain by harmonizing the gains found in this with (or into) ALF or otherwise improving ALF rather than adding another processing stage.

It was remarked that JCTVC-D119 is an effort in that direction.

JCTVC-D183 CE8 Subset3: Cross verification on Picture Quadtree Adaptive Offset (JCTVC-D122) [I.-K. Kim, T. Lee (Samsung)]

Cross-check of JCTVC-D122. The source code was checked and compiled, and found matching results.

JCTVC-D123 CE8 Subtest3: Controlled Clipping [Yu-Lin Chang, Chih-Ming Fu, Yu-Wen Huang, Shawmin Lei (MediaTek)]

This contribution described a proposal on controlled clipping (CC). The main concept of CC is to signal the minimum and maximum of original pixel values for predicted or reconstructed pixels to be clipped within the range between the minimum and the maximum. In this way, the distortion between the original video and the decoded video can reportedly be reduced. The proponent applied CC at four different positions of the coding path, i.e. post-prediction, post-reconstruction, post-deblocking, and post-adaptive loop filtering (ALF). Moreover, CC also can be applied as a post processing outside of the entire decoding process and prediction loop. The in-loop CC can be applied at each of the four positions, while the post-loop CC is applied at the output of the decoder. The output pixels of the post-loop CC are not stored in the reference picture buffer but only used for display. Different in-loop/post-loop CC options are tested, and it was reported that the post-loop CC (but with CC syntax) can achieve the best coding efficiency. Comparing with the anchor in JCTVC-C500, the post-loop CC could reportedly achieve 0.6% and 0.4% bit rate reductions for high efficiency random access (HE-RA) configuration and high efficiency low delay (HE-LD) configuration, using CC information sent in the slice header. When the CC information is sent in another NAL unit rather than, the bit rate reductions dropped to 0.4% and 0.2% for HE-RA and HE-LD, respectively, due to the increased overhead. There was reportedly almost no increase in encoding or decoding time.

It was asked how the encoder decides what clipping range to indicate. In the tested method, the encoder measured the minimum and maximum sample values of the source video.

The proposal suggested having a clipping range per component, with syntax supporting either sending three ranges (Y, Cb, Cr) or two ranges (Y and chroma) or just a "broadcast legal" flag, or predictive coding from picture to picture.

It was asked whether ranges in the RGB domain might be better to signal than in the YUV domain, as conversion to RGB is common for display.

It was remarked that, at least when the clipping range is just the "broadcast legal" range, it is likely to already be understood that values outside the range are interpreted as visually clipped to black and white, and the PSNR measure is not really producing any benefit to the interpretation of the values.

It was remarked that if this is operating out of the loop, if it is desirable, it could be handled as something the decoder is not required to do (e.g., using an SEI message).

It was remarked that cascaded encoding followed by decoding followed by re-encoding with clipping between the two encoding stages might actually degrade the signal, as some "headroom" and "footroom" may actually be desired in the signal flow chain. Moreover, the clipping could result in failing to detect, at a destination, that the signal characteristics are mal-adjusted at the source.

Some participants characterized this technique as perhaps an artificial PSNR boosting measure in a manner that is not likely to actually provide a visual picture quality benefit.

JCTVC-D077 CE8 Subset3: Verification results of MediaTek's Proposal (JCTVC-D123) [I. S. Chong, M. Karczewicz (Qualcomm)]

Cross-check of JCTVC-D123. The results reportedly matched those reported by MediaTek.

11.3 Discussion and Conclusions

11.3.1 Subset 1: Deblocking and debanding

For Subset 1, the initial viewing results seem inconsistent overall, and further viewing was deemed needed.

A revision of the summary report was made to include a report of the viewing. It was reported that the visual quality results seem very similar overall, to the degree that attempting to perform scoring appeared unnecessary because the degree of differences was so small.

As a result, it was suggested that PSNR and complexity be used for further evaluation of Subtest 1. We appear unable to confirm claims of visual quality improvement.

It was remarked that for intra coding, JCTVC-D163 has higher complexity than the others, although the proponent said that the total decoder runtime increase was only 1%. The deblocking part of the processing was reportedly increased about 20%.

None of these three proposals were suggested to be decreasing complexity.

It was asserted that there may some differences in quality that are observable from still-picture snapshots.

In JCTVC-D085, the PSNR results indicated a range from negligible to 1.6% in PSNR impact, with the MediaTek JCTVC-D163 proposal providing larger gain. The SKT/SKKU proposal affected only intra blocks, and provided about 0.5% gain on intra (with approximately no impact on other cases, as would be expected). The Microsoft and NEC proposals averaged between approximately no impact and a small degradation of PSNR. The NEC proposal adds pseudo-noise, which would not be expected to provide PSNR benefit.

There are related non-CE contributions JCTVC-D214, JCTVC-D263, and JCTVC-D377.

JCTVC-D377 reported about the same complexity as the current deblocking design, with a reported improvement of about 1.2% in PSNR performance (cross-verified and supported by the cross-verifier). The contributor of JCTVC-D377 indicated that some of the runtimes reported in their contribution were from (unreliable) cluster simulations. The cross-checker used a cluster, but a more homogeneous cluster and reported basically no change in decoding times. Several participants indicated that the changes in JCTVC-D377 were straightforward and supported its adoption at this time.

JCTVC-D214 proposed an asserted complexity reduction and parallelization improvement (making decisions based on the unfiltered signal). It was suggested that the techniques in JCTVC-D214 should hypothetically be possible to apply to a deblocking filter that has been modified as suggested in the other contributions.

JCTVC-D263 has a similar spirit to JCTVC-D214.

A suggested path was as follows: To adopt JCTVC-D377 with the parallelism improvement from JCTVC-D214 and/or JCTVC-D263, and conduct further study in a CE.

There had not been "blind" viewing of JCTVC-D377. BoG activity (Vittorio Baroncini) was requested to try to get some viewing comments and (Ken McCann) decoding times.

The proponent of JCTVC-D334 / JCTVC-C130 said that the JCTVC-D334 scheme was more similar to the current design than JCTVC-D377, although the proponent of JCTVC-D377 disputed this.

A BoG report was prepared and provided, reporting the following.

After some further blind viewing of JCTVC-D377, JCTVC-D214 and JCTVC-D263, it was reported (by V. Baroncini) that the visual difference between these and the reference was essentially imperceptible (as had been the case with the others previously), to such an extent that there appeared to be no potential benefit to trying a more extensive subjective comparison.

The decoding runtime results that were reported indicated that

- JCTVC-D163 increased decoder runtime by about 1%.
- JCTVC-D214 (parallelism) increased decoder runtime by about 6% (which may be an artifact of how it was implemented).
- JCTVC-D263 (parallelism) increased decoder runtime by about 0.7%.
- JCTVC-D334 increased decoder runtime by about 0.6%.
- JCTVC-D377 had approximately no effect on decoder runtime.

Some participants indicated that they had wanted to study the software used in the JCTVC-D377 proposal but were not able to get access to it, as would have been enabled if a CE had been conducted for that proposal.

It was agreed that JCTVC-D377 should be further studied in a CE.

JCTVC-D214 indicates to make all horizontal and vertical decisions for the DF prior to performing the filtering (and store these decisions for use later), rather than cascading these processes.

JCTVC-D214 should be further studied in a CE.

JCTVC-D263 has two aspects – one is to shift the position of the samples that are used for decision-making so that they are not affected by the first filtering stage, and to change the filtering process to a frame-based rather than CU-based.

JCTVC-D263 should be further studied in a CE.

11.3.2 Subset 2: Wiener-based in-loop filters

Discussed above.

11.3.3 Subtest 3: Controlled clipping and offset

Operating the controlled clipping as an outside-the-loop post-process was reported to be adequate. The clipping range in the reported experiments was established at the whole-frame level based on the range observed in the input video data (e.g. using multi-pass encoding).

It was remarked that such an outside-the-loop indicator could be sent using an SEI message (or something similar).

Regarding the offset proposal (sending a quadtree and sending an offset for each leaf): 1-2% gain.

It was remarked that this seems related to weighted prediction. This led to the discussion reported in the next section.

11.3.4 Discussion topic: Weighted prediction

Weighted prediction is not in the current HM software, although it is part of the AVC design.

It was remarked that synthesized sequences for fade from black, fade to black, and cross-fades were used when designing this for AVC.

It was remarked that several techniques had previously been investigated for HEVC that did not provide a benefit on the proposal test set but might show benefits on other material of the sort that might be used for weighted prediction testing.

It was remarked that good encoder design is important for use of weighted prediction, although simple techniques might suffice for some limited experiment purposes.

It was remarked that proprietary AVC encoders do make somewhat extensive use of this feature.

12 CE9: Motion vector coding

12.1 Summary

JCTVC-D149 CE9: Summary report for CE9 on motion vector coding [J. Jung, B. Bross] (missing prior, uploaded Monday 17th, before meeting)

This document summarized the activities in the Core Experiment CE9 on motion vector coding. A total of 16 companies or universities had registered to the CE. A few email messages were exchanged mainly to coordinate the cross-check activity and exchange the modified versions of the HM0.9 software. Also it was reported that for some topics the contribution was cancelled by the proponent (due to lack of time for running the experiment, or insufficient results).

Three main topics had been addressed:

- Study of the configuration of the Skip, Direct and Merge modes,
- Adaptation and modification of the set of predictors,
- Temporal motion vector memory compression.

The contributions on the CE were summarized as shown in the following table.

	Tester 1	Tester 2 (cross-check)
3.1.b	HHI – JCTVC-D314	Motorola – JCTVC-D248
3.1.c	HHI – JCTVC-D314	Qualcomm – JCTVC-D355
3.1.d	HHI – JCTVC-D314	Orange Labs – JCTVC-D130
3.1.e	HHI – JCTVC-D314	Orange Labs – JCTVC-D132
3.1.f	HHI – JCTVC-D314	NTT DOCOMO – JCTVC-D233
3.1.g	Mediatek – JCTVC-D133	Intel – JCTVC-D172
3.1.h	JVC Kenwood – JCTVC-D118	Mitsubishi – JCTVC-D097
3.1.i	HHI – JCTVC-D314	NTT DOCOMO – JCTVC-D233
3.1.j	HHI – JCTVC-D314	SKKU – JCTVC-D330
3.1.k	HHI – JCTVC-D314	NTT DOCOMO – JCTVC-D233
3.1.l	HHI – JCTVC-D314	NTT DOCOMO – JCTVC-D233
3.1.m	NTT DOCOMO – JCTVC-D233	HHI – JCTVC-D314
3.1.n	NTT DOCOMO – JCTVC-D233	Orange Labs – JCTVC-D134
3.1.o	NTT DOCOMO – JCTVC-D233	Samsung – JCTVC-D410
3.1.p	NTT DOCOMO – JCTVC-D233	ETRI & Kyunghee University – JCTVC-D277
3.1.q	HHI – JCTVC-D314	NTT DOCOMO – JCTVC-D233
3.1.r	HHI – JCTVC-D314	NTT DOCOMO – JCTVC-D233
3.1.s	Samsung – JCTVC-D411	Sony – JCTVC-D413
3.1.t	Samsung – JCTVC-D411	Sony – JCTVC-D413
3.1.u	NTT DOCOMO – JCTVC-D233	HHI – JCTVC-D315
3.2.c	Sony – JCTVC-D301	Canon – JCTVC-D117
3.2.d	NTT DOCOMO – JCTVC-D231	Sharp – JCTVC-D067
3.3.b	Sharp – JCTVC-D072	NTT DOCOMO – JCTVC-D232

12.2 Contributions

JCTVC-D067 CE9: Verification of Docomo's contribution on motion vector coding [Andrew Segall, Jie Zhao]

JCTVC-D068 CE9: Verification of Orange's contribution on motion vector competition [Kiran Misra, Jie Zhao, Andrew Segall] (missing prior, uploaded Friday 21st, second day of meeting)

JCTVC-D072 CE9: Reduced resolution storage of motion vector data [Yeping Su, Andrew Segall]

JCTVC-D097 Report of CE9 on Motion Vector Coding [Shun-ichi Sekiguchi, Kazuo Sugimoto (Mitsubishi)]

JCTVC-D117 CE9: Cross verification about the adaptation and modification (3.2.c) of the set of predictors [P. Onno]

JCTVC-D118 CE9: Report on experiment 3.1.h [Shigeru Fukushima]

JCTVC-D130 CE9: verification of experiment 3.1.d [J. Jung, G. Clare]

JCTVC-D132 CE9: verification of experiment 3.1.e [J. Jung, G. Clare]

JCTVC-D133 CE9: Crosscheck of HHI's AMVP-based Skip/Direct and PU-based Merging by MediaTek [Jian-Liang Lin, Yu-Wen Huang]

JCTVC-D134 CE9: verification of experiment 3.1.n [J. Jung, G. Clare]

JCTVC-D172 CE9: Cross-check of PU-based merge mode result (Test 3.1.g) [Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)]

JCTVC-D231 CE9: 3.2d Simplified motion vector prediction [A.Fujibayashi (NTT DOCOMO), F. Bossen (DOCOMO USA Labs)]

JCTVC-D232 CE9: Cross verification for subtest 3.3 temporal motion vector memory compression (JCTVC-D072) [A. Fujibayashi (NTT DOCOMO)]

JCTVC-D233 CE9: 3.1 PU merge & skip tools and proposed improvements [Y. Suzuki, TK Tan (NTT DOCOMO)]

JCTVC-D315 Crosscheck of NTT DOCOMO's Proposal JCTVC-D233 on Merge Improvements [B. Bross (Fraunhofer HHI)]

JCTVC-D248 CE9: Cross check with JCTVC-C509 (3.1.b) [Yue Yu, Krit Panusopone, Limin Wang] (missing prior, uploaded 20th, first day)

JCTVC-D277 CE9: Cross verfication of experiment 3.1.p [Seyoon Jeong, Hui Yong Kim, Jin Soo Choi, Kyungyong Kim, Sangmin Kim, Gwanghoon Park]

JCTVC-D301 CE9: Result of 3.2.c [Kazushi Sato] (initial version rejected as a placeholder upload)

JCTVC-D314 CE9: Motion Vector Coding Test Report [B. Bross, S. Oudin, D. Marpe, H. Schwarz, T. Wiegand (Fraunhofer HHI)]

JCTVC-D330 CE9: Cross-verification result of (3.1.j) by SKKU [Jungyoup Yang, Kwanghyun Won, Byeungwoo Jeon]

JCTVC-D355 CE9: Cross-check report from Qualcomm on Modified AMVP and PU-Merge (CE9.3.1c) [W.-J. Chien, M. Karczewicz]

JCTVC-D410 CE9: Cross verification result on subtest 3.1.o (JCTVC-D233) of NTT DOCOMO [I.-K. Kim, T. Lee (Samsung)]

JCTVC-D411 CE9: Test results on subtest 3.1.s and 3.1.t [I.-K Kim, T. Lee (Samsung)]

JCTVC-D413 CE9: cross-check result of 3.1s and 3.1t [Yoshitaka Morigami, Kazushi Sato] (late registration Monday 17th, uploaded Tuesday 18th, before meeting)

12.3 Discussion and Conclusions

12.3.1 First part of CE9: Study of the configuration of the Skip, Direct and Merge modes

In summary, it was reported that PU merge seems generally better than CU merge.

Disabling direct mode seems to provide improvements, as this has some redundancy with PU merge.

Combination 3.1.e and 3.1.t seem to have the best overall compression efficiency – with approximately 1% and 1.2% improvement overall for these two. Both of these were indicated, by runtime measures, to actually reduce complexity relative to the anchors.

It was remarked that PU merge may be difficult to use, especially in hardware, due to a difficulty in parallelization for that feature. Another participant commented that this is also true for other schemes as well, such as direct mode (at least for spatial direct mode).

A participant that had contributed JCTVC-D233 ("3.1.u" above, which was not actually part of the original CE plan) remarked that this contribution is closely related and takes into account some of the conclusions of this work and provides further gain and complexity reduction. That contribution reportedly also removed the redundancy in splitting of CUs and PUs.

A participant remarked that JCTVC-D370 should perhaps be considered in relation to this, as it contains an improvement of LCEC entropy coding. Another participant, somewhat similarly, remarked that it may be best to pay the most attention to the results from the CABAC entropy coder, under the assumption that the other entropy coder would eventually be improved to more closely match its performance. A participant indicated that the basic relative results would be unlikely to change if only the CABAC cases were considered.

A participant remarked that a parsing problem exists in the use of temporal MV prediction in the current HM design and that there is at least one contribution JCTVC-D197 proposing to fix that. A participant remarked that all of the best performing proposals have temporal MV prediction, and that a similar fix could probably be applied to all or most of them without substantial impact on their relative performance to each other.

At this point, the JCTVC-D314 "3.1.e" and JCTVC-D411 "3.1.t" combinations appeared to be the best among what was planned to be tested in the CE. Those and JCTVC-D233 were then further reviewed (possibly related other contributions) before making a decision.

In regard to JCTVC-D233: Several aspects of the document relate to JCTVC-D314 "3.1.e". Section 3 of the document is a new proposal to remove redundancy between CU and PU splitting. Two variants were proposed.

The first variant, without asymmetric motion partitioning (AMP), reportedly showed, relative to JCTVC-D314 "3.1.e", about 0.1% reduction of coding efficiency with a substantial reduction of encoder runtime (roughly 25%).

A participant remarked that it may be possible to achieve the same degree of encoder simplification without modification of the syntax, semantics, or decoding process. The participant also remarked that a different syntax modification may provide a simpler way to accomplish a similar result. It was suggested that experiment results for these alternative approaches could become available during the meeting.

There was a suggestion to decompose this into two elements, initially focusing on the relationship with "3.1.e". The group then discussed these elements as follows;

- Removal of NxN split of CU into 4 PUs for inter cases except for the smallest CU size. It was noted that JCTVC-D314, JCTVC-D087 and JCTVC-D356 all advocated this same change.

Decision: It was agreed that this should be done.

- Replacing 2NxN and Nx2N PU splits with new "partial merge" modes, which reduces the signaling information for this selection. We revisited this aspect later during the meeting.

It was remarked that removing the NxN PU split for the smallest CU size also may be good to do. Further study on that topic was suggested (e.g., in a CE).

Further discussion of "3.1.t" versus "3.1.e":

The difference between "3.1.e" and "3.1.t" is that in "3.1.t" a skip mode is enabled with derivation of the MV from MVC, whereas in "3.1.e", there is no skip mode but there is a merge with no residual (which the encoder currently selects only if the residual coding results in no residual).

A participant remarked that "3.1.t" should be used for reasons of draft stability, and another participant thought that "3.1.t" may be better for encoder parallelism.

The second variant, with the asymmetric motion partitioning (AMP) feature added, reportedly showed, relative to JCTVC-D314 "3.1.e", about 0.7% improvement of coding efficiency with some increase of encoder runtime (roughly 9%).

It was remarked that the prior asymmetric motion partitioning (AMP) feature was not included in the WD, and this variant adds it back in some way – and it may be desirable to compare this proposed method for that feature with the prior proposed method for that feature.

BoG activity for further discussion was requested, coordinated by T.K. Tan & W.-J. Han. This resulted in the submission of JCTVC-D441. Please refer to the notes on that report for additional conclusions.

12.3.2 Second part of CE9: Adaptation and modification of the set of predictors

JCTVC-D301 "3.2.c" proposes reordering the predictor to put the temporal predictor first. It was tested with merging off, and provided no reported benefit relative to merge enabled in the anchor.

A cross-checker JCTVC-D117 tried enabling merging in combination with this and reported a benefit. The combination reportedly provides about 0.2% benefit in the HE RA case (relative to merge enabled in the anchor). It was remarked that a previous similar test was done in Guangzhou with better results.

JCTVC-D164 is related.

JCTVC-D231 "3.2.d" proposed three simplifications: 1) removing the median predictor candidate, 2) disabling a pruning process of MV prediction candidates based on MV differences, 3) changing the method of choosing the MV predictors for the left and above predictors and reducing the number of candidate predictors. It was reported that the first of these modifications results in no loss in coding efficiency, the second results in 0.2% average loss, and the third results in 0.2% average gain.

JCTVC-D303 was suggested to be related – corresponding to the first topic investigated in 3.2.d.

JCTVC-D055 was suggested to be related to the third aspect.

Decision: These three simplifications (from JCTVC-D231) were adopted.

12.3.3 Third part of CE9 "Temporal motion vector memory compression"

There was one primary contribution on this subject, which was JCTVC-D072 (with a cross-check in JCTVC-D232). MVs have been stored on a basis as small as a 4x4 basis (up to 2 MVs per block). This proposal reportedly reduces the necessary storage by a factor of 16 by storing them on a 16x16 basis instead. A coding efficiency impact averaging approximately 0.5% was reported.

Decision: This simplification was adopted (as the memory savings is very substantial).

13 CE10: Number of intra prediction directions

13.1 Summary

JCTVC-D100 CE10: Summary of CE10 on number of intra prediction directions [Kazuo Sugimoto (Mitsubishi)]

An increased number of directions for intra prediction was introduced in the TMuC and reportedly will be integrated into the HEVC Test Model. The purpose of this CE was to characterize the performance and complexity of using different numbers of intra prediction directions. The characterization was performed by investigating the coding efficiency improvement in terms of BD-BR performance, and by determining the complexity increase for both encoding and decoding using variety of combinations of intra prediction directions for each block size.

13.2 Contributions

JCTVC-D050 CE10: Cross-check report from Institute for Infocomm Research [Y. H. Tan, C. Yeo, Z. Li (I2R)]

JCTVC-D063 CE10: Cross-check report from INRIA on number of intra prediction directions [Laurent Guillo, Ronan Boitard]

JCTVC-D101 CE10: Cross-check report on number of intra prediction directions from Mitsubishi [Kazuo Sugimoto, Shun-ichi Sekiguchi (Mitsubishi)]

JCTVC-D102 CE10: Cross check report for number of intra prediction directions from Toshiba [Akiyuki Tanizawa, Taichiro Shiodera (Toshiba)]

JCTVC-D198 CE10: Cross verification of directional intra prediction configurations [J. Lainema, K. Ugur (Nokia)]

JCTVC-D207 CE10: Cross-check report on the number of intra prediction directions [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda]

JCTVC-D291 CE10 : Crosscheck report for number of intra by MediaTek [Mei Guo, Xun Guo]

JCTVC-D358 CE10: Samsung's crosscheck on number of intra prediction directions [J.-H. Min, J. Chen (Samsung)]

13.3 Discussion and Conclusions

Using only 3 instead of 5 modes for 64x64 reportedly does not change the bit rate (-0.004) – the additional 2 modes seem useless.

Using 9 instead of 34 modes for 32x32 increases the bit rate slightly for HE (+0.13), and does not change for LC (-0.03). However, this is not uniform over classes; the gain by using more modes is mostly achieved in class E (0.4%).

Based on the results, the suggestion was made to use following number of modes: 4x4:17; 8x8&16x16:34; 32x32: 9; 64x64:3. After discussion, the recommendation is to keep 34 modes also in the 32x32 size, as it seems to be beneficial for some cases, the restriction would not have implications on necessary decoder complexity, and an encoder could exclude those modes anyway if they are undesirable.

Decision: Change HM/WD, in 64x64 use only 3 intra modes (DC, horizontal, vertical); intra prediction for other block sizes unchanged (17 directions for 4x4, 3 directions for 64x64, 34 directions for others).

14 CE11: Coefficient scanning and coding

14.1 Summary

JCTVC-D240 CE11: Summary report on coefficient scanning and coding [V. Sze (TI), K. Panusopone (Motorola), J. Chen (Samsung), T. Nguyen (Fraunhofer HHI), M. Coban (Qualcomm)]

This contribution is a summary of core experiment 11, Coefficient scanning and coding. Twelve companies and one university have been registered in CE11 and eight proposed tools from five proposals have been evaluated on the condition defined in document by the Software Ad Hoc Group. A sixth proposal was withdrawn. In addition to measuring the coding efficiency, a count of significant_coeff_flag bins is reported. Methods of scan pattern selection and signaling are also reported. Only high efficiency configuration results are reported.

14.2 Contributions

JCTVC-D061 CE11: Evaluation of Transform Coding tools in HE configuration [T. Nguyen, D. Marpe, H. Schwarz, T. Wiegand]

This document reports results from Fraunhofer HHI for the tests of core experiment 11.

Issues tested (BR increase for intra/RA/LD):

- Disabling adaptive scan order (direction of diagonal scanning) as in HM 1.0 for coding of the significance map increase 0.35/0.22/0.19
- Disabling context model selection as in HM 1.0 for significance flag increase 1.76/1.41/2.78
- Disabling context model selection as in HM 1.0 for last significance flag 0.04/0.27/0.86
- Disabling context model selection as in HM 1.0 for the absolute transform coefficient levels 0.58/0.20/0.74

Among these four, adaptive scanning gives least benefit, some arguments were brought about the complexity.

Total bit rate loss for all four: 2.59/1.92/3.75.

Encoding/decoding time reported to change marginally (within 1-2%)

Decision: Disable/replace adaptive scan order (see JCTVC-D239).

JCTVC-D113 CE11: Cross-check report for Fraunhofer HHI’s proposal [Yukinobu Yasugi, Tomoyuki Yamamoto]

JCTVC-D190 CE11: Coding efficiency of tools in HHI_TRANSFORM_CODING (JCTVC-A116) [V. Sze (TI)]

JCTVC-D236 CE11: Cross-check report from Motorola Mobility for HHI's adaptive scan (JCTVC-A116) [Jian Lou, Krit Panusopone, Limin Wang]

Cross-checker reports that disabling adaptive scan gives a benefit of 4% encoding time reduction

JCTVC-D195 CE11: Simplified context selection for significant_coeff_flag (JCTVC-C227) [V. Sze, M. Budagavi (TI)]

HHI_TRANSFORM_CODING uses a highly adaptive context modeling approach for the significance map, where context selection for significant_coeff_flag depends on coefficients in 10 neighboring positions. While it provides coding gains between 1.4% to 2.8%, it greatly increases the complexity of context selection when coding significant_coeff_flag. In this contribution, a simplification of the context selection was proposed. Neighbor dependency was reduced from 10 to 8, then to 4. The number of contexts required for significant_coeff_flag is also reduced from 128 to 108. These modifications were implemented in TMuC-0.9 and their coding efficiencies were evaluated. Reducing from 10 to 8 has no reported coding loss, while reducing from 10 to 4 (reducing the dependency by more than half) has a coding loss between 0% to 0.2%. This simplified context selection had a negligible effect on the number significant_coeff_flag bins.

Reducing from 10 to 8 contexts does not lose compression efficiency

Reducing from 10 to 4 contexts loses compression efficiency 0.2%/0.1%/0% for intra/RA/LD

Reduction of encoding time reported to 98/92/92 and 95/93/91 for the 10->8 and 10->4 reduction cases

Decoding time changes are within noise; also encoding time numbers could be questionable (confirmed by one cross-checker, not confirmed by the other).

The number of contexts most probably is less relevant for software than hardware implementation.

JCTVC-D244, JCTVC-D260 & JCTVC-D262 are related.

Where is the optimum cutoff point between 8 and 4? Is a lower number of contexts useful for parallelization?

JCTVC-D062 CE11: Cross-check report from HHI for TI's proposal JCTVC-C227 [T. Nguyen, D. Marpe, H. Schwarz, T. Wiegand]

JCTVC-D075 CE11: Cross-check report from Panasonic for TI's proposal [Hisao Sasai, Takahiro Nishi]

JCTVC-D244 Context selection complexity in HEVC CABAC [V. Sze (TI)]

CABAC is a well known throughput bottleneck in video coding implementations. This is due to the many feedback loops in the CABAC, several of which are in the context selection. A common technique used in practice is speculative computation which aims to increase the throughput of CABAC. However, this comes at a cost of increased number of computations per bin. With the introduction of HHI Transform Coding into HM1, the data dependencies in context selection have become even stronger. The number of contexts for significance map in HEVC is almost 2x more than AVC, thus tightening this bottleneck in the context selection of CABAC. This also increases implementation area cost, as the context memory needs to be larger.

This contribution discussed the approach of "speculative computation" demands for possibly lowest number of contexts. It is said that this method is widely used when implementing CABAC in a pipeline architecture.

JCTVC-D260 Parallel processing friendly simplified context selection of significance map [C. Auyeung, W. Liu (Sony)]

This contribution proposed a reportedlyparallel processing friendly and lower complexity alternative to the context selection of significance map in TMuC 0.9. The proposed context selection removes the data dependency on the left boundary, bottom boundary and scan direction. It reduces the maximum size of the neighborhood needed for context selection from 10 to 5 pixels. It reportedly resulted in % BD BR improvements of 0.0, 0.0, -0.1 relative to the anchor for Intra HE, Random Access HE, and Low Delay HE test cases respectively.

In contrast to JCTVC-D194, the number of context models was not changed; only the number of neighbors used to derive the probabilities was reduced.

JCTVC-D242 provides a cross-check and confirms the results.

Various similar contributions were submitted, this solution is reducing the number of neighbors used in the context to half without affecting compression performance.

Decision: Adopted.

JCTVC-D242 Cross-check of Sony's simplified context selection (JCTVC-D260) [V. Sze (TI)]

JCTVC-D242 provides a cross-check and confirms the results.

JCTVC-D262 Parallel Context Processing for the significance map in high coding efficiency [J. Sole, R. Joshi, I.S. Chong, M. Coban, M. Karczewicz]

This proposal presents a technique for the parallelization of context processing to improve the throughput of the entropy coder for the high efficiency case. The position of the last significant coefficient is encoded before the position of the other significant coefficients within a block. The position of the last coefficient is encoded explicitly by signaling its X and Y coordinates with a unary code. The X and Y signaling is independent. The context derivation for the significance map is simplified to further enhance parallelization. The parallelization improvements of the proposal reportedly come at no cost in performance. The BD BR for the high efficiency intra, random access, and low-delay configurations is reported as 0.06%, 0.01%, and -0.17%, respectively.

If the last significant coefficient is found within the first 10 coefficients, then a set of contexts depending solely on the scan position is used. Otherwise, the usual contexts are used.

JCTVC-D212 Verification results of Qualcomm's Proposal JCTVC-D262 on Parallel Context Processing [T. Yamakage (Toshiba)]

JCTVC-D239 CE11: Report on zigzag scan performance for CABAC on TMuC0.9 [Jian Lou, Krit Panusopone, Limin Wang]

The target of this document is to verify the performance of zig-zag scan with CABAC in transform coding for high efficiency test conditions. The simulations were conducted using TMuC0.9 software with Motorola Mobility's modifications. The code modifications reportedly clean up the redundancies introduced by adaptive scan in order to achieve accurate speed. Bit-exact rate-distortion performance as that provided in JCTVC-D236 was reportedly achieved. The anchor results were obtained with adaptive scan and the tested results were obtained with zig-zag scan.

In principle, this is the same as disabling adaptive scan order, however a different zig-zag scan implementation was used. Reported encoding time goes down to 91-95%; decoding time does not change.

This is certainly due to multiple encoding passes in RDO.

The direct implementation of the zig-zag scan is more efficient than disabling adaptive scanning by a switch in the current reference SW, but it produces the same bitstream and compression results.

Decision: Adopt – see discussion and conclusions section.

JCTVC-D309 CE11: Cross-check of Motorola's proposal JCTVC-D239 by Huawei [H. Yang, J. Zhou]

JCTVC-D400 CE11: Cross verification of Motorola's zigzag scan for CABAC/PIPE [M. Coban]

JCTVC-D360 CE11: Low-complexity adaptive coefficients scanning [V. Seregin, J. Chen, W.-J. Han (Samsung)]

In this document, Adaptive Coefficient Scanning (ACS) with three scanning pattern is investigated and tested. The scanning index for every Transform Unit (TU) is explicitly signalled to the decoder side in the method proposed in JCTVC-C205. In the different method, mode dependent coefficient scanning proposed in JCTVC-D393 is used to derive scan mode for intra 4x4 and 8x8 blocks to reduce encoder complexity. Experimental results reportedly show that the proposed ACS provides 1.0%, 0.6% and 0.6% BD BR gain in high efficiency (HE) configurations and 0.1%, 0.2% and 1.1% BD BR gain in low complexity (LC) configurations, respectively for intra-only, random access, and low-delay test conditions.

- In intra coding, scanning pattern is derived from the mode.
- In inter coding, scanning pattern is explicitly signalled.
- Loss of performance in LC case is explained by inefficiency of LCEC for intra (as reported elsewhere and resolved by new codenumber mapping method).
- "optimized" version still uses the direction adaptive scanning of HM for diagonal.
- Part of the gain in inter (particularly RA) also comes from intra coded pictures or blocks.

JCTVC-D146 Cross-verification report for Samsung and Qualcomm's proposal from Microsoft [J. Xu (Microsoft)] (missing prior, uploaded Thursday 20th, before meeting)

JCTVC-D189 CE11: Cross-verification of Samsung's low-complexity adaptive coefficients scanning (JCTVC-C205) [V. Sze (TI)]

JCTVC-D320 CE11: Cross verification of Samsung's proposal JCTVC-C205 [K. Ugur (Nokia)]

JCTVC-D382 CE11: Cross-verification of Samsung's low-complexity adaptive coefficients scanning (JCTVC-C205) [C. Auyeung]

JCTVC-D393 CE11: Mode Dependent Coefficient Scanning [Yunfei Zheng, Muhammed Coban, Joel Sole, Rajan Joshi, Marta Karczewicz]

In this contribution, a mode dependent coefficient scanning order selection scheme was proposed in order to improve the HEVC coding performance. In the proposed scheme, the "best" scanning order for the significance map is selected among HHI transform coding (TC) zig-zag, horizontal, and vertical scans based on the transform unit size and intra prediction mode. The proposed scheme reportedly achieves 1.0% BD BR reduction on average for the high efficiency intra configuration. There was reportedly no encoder/decoder complexity increase when compared to the TMuC 0.9 default setting.

- 3 scan directions
- Use direction-adaptive scanning from HM for diagonal scan case
- Did not use context-adaptive scanning for inter
- Explicit signalling was tested as well; matches with JCTVC-D360 results
- No test for LC case.

JCTVC-D453 Cross-check report of mode dependent transform coefficients scanning from JCTVC-D393 [J.Chen, V.Sze, K.Panusopone, A.Tabatabai, M.Coban] (late registration Wednesday 26th after start of meeting, uploaded Wednesday 26th, near the end of the meeting)

This contribution summarized cross-check activities on the transform coefficients scanning method in CE11. Mode Dependent Coefficient Scanning scheme of JCTVC-D393.

The software source code was verified to be a match with the proposal. High efficiency configuration results were partially cross-checked by Texas Instruments (Intra only configuration are fully cross-checked). Low complexity configuration results were cross-checked fully by Samsung and partially by Sony.

- Was also checked compared with the coefficient VLC fix from JCTVC-D374
- Gains for HE confirmed
- For LC, gains are 0.6%, 0.3% and 0.1%
- Only affects 4x4 and 8x8

Decision: Adopt the adaptive scanning method from JCTVC-D393 as tested here. (Revised in Track B Wednesday afternoon.)

JCTVC-D456 CE11: Crosscheck of Qualcomm's Mode Dependent Coefficient Scanning in JCTVC-D393 by MediaTek [C.-Y. Chen, Y.-W. Huang] (late registration Thursday 27th after start of meeting, uploaded Thursday 27th, near the end of the meeting)

No detailed discussion of this contribution was considered necessary

JCTVC-D359 CE11: Cross-verification of Qualcomm's low-complexity adaptive coefficients scanning [V. Seregin, J. Chen (Samsung)]

JCTVC-D424 CE11: Cross-check results for Qualcomm's Proposal JCTVC-D393 T. Nguyen, D. Marpe, H. Schwarz, T. Wiegand (late registration Thursday 20th after start of meeting, uploaded Friday 21st, second day of meeting)

14.3 Discussion and Conclusions

Issues identified in the CE:

- Decision: Potential reduction of context sizes without penalty in compression efficiency – beneficial for pipeline implementations – adopt solution from JCTVC-D260.
- Decision: Conclusion on scanning: Disable/remove adaptive scan order from HM – replace by zig-zag scan implementation from JCTVC-D239.
- Continue CE on other aspects of adaptive scanning. Clarify whether this is useful for inter (at least RA case seems to give little gain)? Is it justifying the additional complexity? This should include investigations in terms of complexity (beyond computation time), parallelization etc.
- Decision: Adopt adaptive scanning for intra JCTVC-D393 after being verified in JCTVC-D453; from the results (JCTVC-D360, JCTVC-D393, JCTVC-D374, JCTVC-D049), as it had not been obvious whether the mode-dependent adaptive scan switching would work well for both HE and LC intra.
- Continue CE on other aspects of CABAC (w.r.t. parallelization, complexity; separate encoding of last coefficient, JCTVC-D262, JCTVC-D219 etc.)

15 CE12: Adaptive motion vector resolution (AMVR)

15.1 Summary

JCTVC-D362 CE12: Summary Report of Adaptive Motion Vector Resolution [W.-J. Chien]

This contribution was a summary of CE12: Adaptive motion vector resolution. Eight companies had been registered in CE12 and two proposed tools had been evaluated on the common condition with cross-verification for each: JCTVC-D394 AMVR, JCTVC-D325 AMVR with DIF

15.2 Contributions

JCTVC-D069 CE12: Verification of Qualcomm's contribution on AMVR [Andrew Segall, Jie Zhao]

JCTVC-D153 CE12: Cross-check result of Nokia's adaptive MV resolution with directional filters by Sejong Univ./SKT [Hyoungmee Park, Ju Ock Lee, Joo-Hee Moon, Jeongyeon Lim]

JCTVC-D292 CE12 : Crosscheck of Nokia's adaptive MV resolution by MediaTek [Xun Guo, Jicheng An]

JCTVC-D325 CE 12: Nokia proposal on adaptive MV resolution with directional filters [K. Ugur, J. Lainema (Nokia)]

JCTVC-D361 CE12: Cross-verification of Qualcomm's experimental results of AMVR by Samsung [E. Alshina, W.-J. Han, A. Saxena (Samsung)]

JCTVC-D394 CE12: Adaptive Motion Vector Resolution from Qualcomm [W.-J. Chien, P. Chen, M. Karczewicz]

15.3 Discussion and Conclusions

Since DIF (used in JCTVC-D325) is no longer planned to be included in the HM, it was suggested to focus on JCTVC-D394.

Relative to the anchor, JCTVC-D394 reportedly provided approximately 1.3% gain, with roughly 7% increase in encoder complexity, and 5% increase in decoder runtime for RA and 5% decrease in decoder runtime for LD. This AMVR proposal was reportedly somewhat different than what had previously been in the TMuC. As proposed, in the HE case, the anchor uses 12 taps, and the AMVR proposal uses (the same) 12 taps for the 1/4 grid positions and 8 taps for the 1/8 grid positions.

On a PU basis, either 1/4 grid or 1/8 grid resolution MVs are indicated (using a flag). For bipredictive cases, each MV has (the equivalent of) such a flag.

It was noted that making this decision at the encoder side adds complexity. This complexity was mitigated in the proposal by the use of fast (hierarchical) search.

For chroma, 1/16th position bilinear MC interpolation was used for the proposal.

Since we have decided to change the luma and chroma interpolation filters, the benefit for this technique may be different in the modified context. The exact impact of that change is unknown.

It was remarked that the prior implementation of AMVR in the TMuC context seemed to have a messy impact on the software.

Some participants felt that the need to support the additional positions in the decoder may not be justified by the quantity of reported gain.

It was recommended to further test the scheme in the new context (e.g., in a CE).

16 CE13: Intra smoothing

16.1 Summary

JCTVC-D390 CE13: Summary report on intra smoothing [M. Coban, B. Bross, J. Chen]

This document reported a summary of core experiment 13 on intra smoothing. Six companies have been registered in CE13 and four proposed tools from two companies have been evaluated according to conditions in CE13 core experiment description. Each proposal had a tool that performed lookup table based intra reference smoothing that depended on the intra prediction mode and block size. A second tool that combined the lookup table and signaling was proposed. Coding efficiency and complexity results were presented.

Gain of best proposal (MDHS) is 0.5% for HE and 0.9% for LC.

Comments:

- 2-stage Recursive lowpass filter is used; this does not match with the actual approach described in the CE document (LUT based).
- Do we need smoothing? Most probably yes, as we had one in AVC.

Would a solution without switching be sufficient? To be determined.

16.2 Contributions

JCTVC-D282 CE13: Mode Dependent Hybrid Intra Smoothing [Yunfei Zheng, Muhammed Coban, Marta Karczewicz]

In this contribution, a mode dependent hybrid intra smoothing scheme was proposed to improve the coding performance. In the proposed scheme, a hybrid approach which combines the mode dependent filter selection and explicit filter signaling is used to select a filter for smoothing the prediction samples. The proposed scheme reportedly results in 0.5% and 0.9% BD BR reduction on average for high efficiency and low complexity intra configuration respectively. The average encoding/decoding time has no significant change comparing to TMuC 0.9's default setting.

- 3 options: no filter, filter1, filter2
- Which filter is used, is derived by two LUTs (most probable filter) from the mode and the PU block size
- For 4x4 and 8x8 only one LUT is used, otherwise it is signalled which one to use.
- For RD opt., only LUT1
- Without LUT signalling (using only LUT1), the gain is 0.3% and 0.7% for HE and LC
- Visual tests? It is said that visual differences are hardly visible
- Current LUTs also contain entries 128x128, should be removed

JCTVC-D103 CE13: Cross check report of Qualcomm's proposal (JCTVC-D282) from Toshiba [Akiyuki Tanizawa, Taichiro Shiodera (Toshiba)]

JCTVC-D176 CE13: Cross-verification of Qualcomm's simplified intra smoothing [J. Chen, J.-H. Min, W.-J. Han(Samsung)]

JCTVC-D305 CE13: Cross-Check Result of 3.2d [Kazushi Sato] (initial version rejected as a placeholder upload)

JCTVC-D313 CE13: Intra Smoothing Test Report [B. Bross, D. Marpe, H. Schwarz, T. Wiegand (Fraunhofer HHI)]

This document reports results of core experiment 13 evaluating intra smoothing tools. Two of the four tested tools perform intra reference sample smoothing based on a mode and block size dependent lookup table. The other two combine the lookup table with signaling. For the best performing tool, encoding times from 101% (intra low complexity) to 97% (low delay low complexity) of the anchor times, decoding times around 98% of the anchor times with bit rate savings from 0.87% (intra low complexity) to -0.04% (low delay low complexity) are reported.

With average bit rate savings between 0.48% and 0.85% for intra only and no significant differences in encoding/decoding time, it was suggested to be concluded that the mode dependent hybrid intra smoothing (MDHIS) is the preferred intra smoothing tool.

JCTVC-D208 CE13: Cross-check report on HHI adaptive intra smoothing [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda]

JCTVC-D363 CE13: cross-verification on HHI's fast adaptive intra smoothing [J. Chen, J.-H. Min (Samsung)]

JCTVC-D402 CE13: Intra Smoothing Test Report [M. Coban, Y. Zheng, M. Karczewicz]

16.3 Discussion and Conclusions

Decision: Adopt MDHIS from JCTVC-D282 (only LUT1 without switching) into HM.

It was remarked that JCTVC-109 uses a similar approach, LUT based filtering for prediction signal – which may be further investigated in CE (which was suggested to be included in an intra prediction CE).

17 Non-CE Technical Contributions

17.1 Clarification and Bug Fix Issues

JCTVC-D027 List of items requiring clarification/action in HM1 [A. Osamoto, M. Zhou, V. Sze (TI)]

This document reported a number of inconsistencies and/or illogical procedures found in TMuC 0.9 software and HM1. These items should be clarified and/or studied.

- CABAC Binarization of refidx: fix provided (JCTVC-D141 element 4, ticket 108 is related).
- Chroma boundary strength calculation for Deblocking filter (JCTVC-D395 is related).
- Order of CABAC sub-block coding within a CU.
- Reference frame management and reference list generation (should mostly carry over from AVC except for aspects decided otherwise, and we should avoid changing the common conditions behavior).
- Chroma intra prediction for chroma intra prediction mode of 4 (need to avoid 2x2 chroma, and most NxN splits have been removed – so no longer needed).

- Weak deblocking filter operation for p1 and q1 (change division by 2 to shift – needs further study).

Decision: The first three items above are agreed (and fixes are already in the software for the first two, although the fixes had previously been disabled). This assumed that an experiment report would be provided showing approximately no coding efficiency impact.

Decision: The fourth item was also agreed in spirit, although this is not the top priority for current software development.

JCTVC-D451 Report on bugfix for CABAC sub-block coding reported in JCTVC-D027 [T. Nguyen, K. Suehring] (late registration Wednesday 26th after start of meeting, uploaded Thursday 27th, near the end of the meeting)

This contribution reported a bug fix for CABAC sub-block coding. It was noted that the bug does not affect coding performance. The fix will be included in the next HM software release.

JCTVC-D395 Comments on chroma deblocking bug fix 119 and WD1 draft text [A. Norkin, S. Sjöberg (Ericsson)]

A bug fix in chroma deblocking has been found and fixed. The bug fix "BUGFIX119" changes the coder behavior. The fix does not match the HEVC draft text in document JCTVC-C403. Other mismatches between the deblocking description and standard text had also been found. Suggested draft text changes were included in the contribution.

JCTVC-D027 is related to the first aspect. See the notes in the discussion of that contribution.

The first uploaded version did not have the second aspect. The second uploaded version was submitted late (on the 23rd).

It was reported that the text is inferior to the software for the deblocking filter, and draft text was provided.

Decision: The text should be fixed.

17.2 HM Settings and Common Test Conditions

JCTVC-D040 PSNR computation on R'G'B' color system [D. Hoang (Zenverge)]

The R′G′B′ color system is commonly used in the specification of digital video capture and display devices. Digital video transmission and compression systems, on the other hand, commonly use the $Y'C_BC_R$ component color system. Digital video compression systems (generally) code the residuals of the Y′, C_B, and C_R components separately. Objective distortion in video compression is commonly measured using the Y′, C_B, and C_R components, with MSE being the most commonly used measure. In the evaluation of a digital video compression system, it can be difficult to juggle three different distortion measurements, especially when trying to balance the coding of the Y′, C_B, and C_R components. In this document, it was proposed to compute a single distortion measure based upon a combined MSE of R′, G′, and B′ components. To illustrate the proposed R′G′B′ distortion measure, an analysis of the simulation results from JCTVC-D035 was provided.

A participant suggested the following combined measure:

$(6 * AVPSNR_Y + AVPSNR_{Cb} + AVPSNR_{Cr}) / 8$.

Another suggestion in the proposal was to compute MSE across all frames and then perform the log conversion (resulting in a arithmetic-mean-MSE-based PSNR rather than a geometric averaging).

A participant suggested to consider a frame with infinite PSNR. Averaging in the log domain results in an infinite average.

A participant suggested that averaging in the log domain seems closer to an averaging in the MOS domain.

A participant recalled the suggestion to measure coding performance by adding up total bits across both the "easy" and "difficult" sequences, and then producing BD measures from that.

Further study on finding improved fidelity measurement practices was encouraged, although using R'G'B' rather than $Y'C_BC_R$ was not supported.

JCTVC-D181 Report on the evaluation of HM versus JM [Seungwook Park, Joonyoung Park, Byeongmoon Jeon]

This document reported an evaluation of HM compared with JM in respect of both coding efficiency and complexity.

Modified anchors (for the Alpha/HE and Beta/HE anchor coding tool configurations) were used, to (approximately) match the QP settings used in the current HM common conditions. "Gamma"/LC anchors were not tested.

Intra-only behavior was additionally tested.

Six common configurations for TMuC 0.9 and Alpha and Beta configurations for JM 16.2 were used. As a result, 17.1% BR for I HE, 36.2% BR for RA HE and 31.2% BR for LD HE were achieved from an objective coding efficiency perspective. And in the decoder side, 75% for I HE, 22% for RA HE and 49% for LD HE complexity increase were observed. At the encoder side, 110% for I HE, 112% for RA HE and 193% for LD HE runtime increases were observed. And the low complexity configuration provides less gain and lower complexity than the HE configuration (as should presumably be the case).

It was remarked that we should not pay too much attention to the speed of reference software, since it depends heavily on code optimization issues.

It was remarked that, to the extent that it is relevant, the JM has been getting faster since the version used here.

It was remarked that the Beta anchor used hierarchical P rather than forward-predictive B coding, and could have benefitted from such usage.

It was remarked that it is important to keep in mind that our actual goal is to measure perceptual quality differences, not PSNR behavior. The contributor did not try any subjective viewing to see to what extent the perceptual quality matched the PSNR behavior.

It was remarked that chroma was not improving as much as luma in these tests. This may simply be a matter of the default relationship established in the designs between luma and chroma quantization fidelities, or could indicate some other issues as well. Another possible explanation was the RDOQ operation in chroma. Another possible explanation was unusual behavior of the chroma R-D points to which the BD curve interpolation and cross-curve averaging was applied.

The proponent suggested that:

- Focus should be put onto reducing intra decoder complexity
- Work should be done on reducing encoder complexity in all cases – and especially for LD.

Contributions to achieve these goals would certainly be welcomed.

JCTVC-D234 Random access support for HEVC [A. Fujibayashi, TK Tan (NTT DOCOMO)]

This contribution reported that random access is not actually properly supported in the HM0.9 software and therefore the common test conditions currently do not simulate true random access capabilities, as the bitstreams that are created cannot be decoded from the middle of the bitstream without causing error propagation.

Two different methods that output random accessible bitstreams were added to the HM0.9 software and simulation results were reported. The first method implements the "closed GOP" instantaneous decoding refresh (IDR) which is useful when simple bitstream editing and splicing are needed. The second method implements an "open GOP" which gives better coding efficiency than the first method. An average coding gain of 4.4% in BD BR for both high efficiency and low complexity test was obtained with the open GOP refresh method compared to the IDR method.

Both random access enabling methods show merit and it was proposed that both these methods should be added to the HEVC description and future HM software releases. When performing core experiments under the random access coding conditions, it was recommended that the open GOP refresh method be used.

Finally, the ability to skip frames and random access into the middle of a bitstream had also been implemented in the HM0.9 software decoder. It was proposed that this feature be added to the future releases of the HM software as well.

The coding efficiency loss of the open GOP method, relative to the current buggy behavior, was reported as 1.9% and 1.1% for HE RA and LC RA, respectively.

Decision: Adopted (although not necessarily using the suggested "deferred decoding refresh" term).

JCTVC-D265 Cross-check results of JCTVC-D234: random access support for HEVC [W.-J. Han (Samsung)]

Cross-check for JCTVC-D234. The cross-checker confirmed the presence of the problem, as well as the impact of the fix.

JCTVC-D356 Three digits to speed up the reference encoder [F. Bossen (DOCOMO USA Labs)] Track A

In this proposal, some relatively minor modifications to the software were suggested. The proposed modifications reportedly result in little coding performance loss (<0.5%) while significantly speeding up the encoder (by up to 37%).

- It is suggested to disable the inter NxN-split mode wherein a CU of size 2Nx2N is split into four PUs of size NxN, except for the smallest CU size of 8x8. This was achieved by changing the preprocessor macro HHI_DISABLE_INTER_NxN_SPLIT from 0 to 1. This aspect had already been planned to be adopted in another recorded decision at the meeting.
- The implemented search method for biprediction is a full-search method and has a range of 8 samples. It was suggested to reduce this range to 4 samples.
- In the motion estimation process, a full search is conducted under certain conditions. A variable iRaster defines the step used in this search. It was suggested to increase the value of this variable from 3 to 5, thereby reducing the number of search points in the motion estimation.

The above changes were motivated for (reference encoder) complexity reduction.

A further modification was provided for obtaining coding efficiency improvement.

- An additional experiment was conducted in which the numbers of reference frames are doubled in the encoder configuration files (NumOfReference=4, and NumOfReferenceB_Lx=2) in addition to the changes proposed above. Combining this with the complexity reductions above resulted in a net improvement of coding efficiency of 3+% relative to the anchors (2% for random access, 4-5% for low delay), with roughly no net runtime increase.

Decision: Adopted all of these changes into the HM reference configurations.

It was remarked that we would likely benefit from having improved (fast) motion search for the HM, and such work was encouraged.

It was also noted that a description of the algorithm used for the search should be put into the HM document.

A corresponding software branch was released as branch 1.0-D356 on the server.

JCTVC-D093 Reference Lists For B Pictures Under Low Delay Constraints [C.S. Lim, S. M. Thet Naing, V. Wahadaniah, X. Jing (Panasonic)]

This contribution provided an investigation report on the different reference picture lists settings when QP fluctuation is used for low delay constraints. The best coding performance can reportedly be achieved when the reference picture list 0 for B pictures is ordered based on quality while reference picture list 1 is ordered based on POC. The proposed technique reportedly provides an average gain of 11.0% for HE and 11.5% for LC settings under LD constraints.

It was remarked that the current software does not match the draft in regard to reference picture list construction, and that this should be fixed.

It was remarked that the planned modified common conditions use more reference pictures in the lists, and the proposal does not (directly) describe/study what to do in this case.

It was noted that the AVC (Beta) anchors used for the CfP used hierarchical QP for LD in the HE case.

It was suggested to use QP scaling in the LD configuration, but not modify the list construction at this time (other than to use more pictures, as proposed in JCTVC-D356).

Decision: It was agreed to use this technique.

QP settings used in the contribution were as follows:

- I: QP
- next "layer": QP+1
- next "layer": QP+4
- next "layer": QP+5

This discussion was later revisited for QP value refinement; after integrating the changes due to JCTVC-D356, the results of that were as follows:

- 12.9% BR reduction LD HE, chroma 30.5% chroma.
- 13.0% BR reduction LD LC, chroma 27.6% chroma.

The encoder and decoder actually ran somewhat faster – due to effectively running at a lower bit rate.

It was noted that the above configuration differs from what we do for RA:

- I: QP
- next "layer": QP+1
- next "layer": QP+2
- next "layer": QP+3

Results of that were as follows:

- 13.4% BR reduction LD HE, chroma 25.7% chroma.
- 13.6% BR reduction LD LC, chroma 23.3% chroma.

It was suggested to use the second case above, to minimize the chance of bit rate effect, for greater consistency with RA case, and for reduced potential for artifacts in the top layers.

Decision: This was agreed.

The results for these experiments described above were to be uploaded as a revision of JCTVC-D356.

It was suggested to study the effect on the overall bit rate operating points. This will be for further study.

Further study of the reference list contruction was also recommended.

JCTVC-D416 LCEC RDOQ speedup [V. Seregin, J. Chen (Samsung)] (late registration Monday 17th, uploaded Monday 17th, before meeting)

This contribution proposed complexity reduction for LCEC RDOQ, reportedly with a minor software modification in a similar manner that already existed in RDOQ for CABAC. The proposed method reportedly provides 0.0%, 0.1% and 0.0% performance loss and with the 81%, 93% and 93% running encoder time in low complexity intra-only, random access, and low-delay configurations, respectively.

The revision reportedly adds only one (relatively brief) line of code.

Cross-verification was provided in (late) document JCTVC-D437.

JCTVC-D374 also relates to this.

Decision: Adopted.

JCTVC-D437 Cross-check of JCTVC-D416 LCEC RDOQ speedup [Jing Wang, Dake He (RIM)] (late registration Sunday 23rd after start of meeting, uploaded Sunday 23rd, fourth day of meeting)

Cross-verification of JCTVC-D416. The software was studied as well as tested. Results matched in all but one case, where there was not a major difference.

17.3 Source Video Test Material

JCTVC-D034 Specification of cropped Super Hi-Vision test sequences [Atsuro Ichigaya, Kazuhisa Iguchi, Shinichi Sakaida, Yoshiaki Shishikui]

The test material ad hoc group has discussed new test materials for JCT-VC activity. It has been suggested that the variety of current test materials is not sufficient. This document contributes some cropped Super Hi-Vision (SHV) sequences as new test materials for beyond HDTV sequences. NHK has previously contributed SHV format test sequences, which are in 7680 x 4680/60 fps/10 bpp format, to JCT-VC (JCTVC-A023). Moreover, JCTVC-C055 reported that these cropped sequences, which were in the 2560 x 1600/60 fps/8 bpp format, were available for evaluating new video coding methods and their performance by TMuC 0.7 (JCTVC-C055). In the Guangzhou meeting, a viewing session was held at which the sequences were viewed. This document described the cropped SHV sequences. The contributor proposed these cropped sequences to become a part of Class A sequences for group testing purposes.

The two sequences are called "Nebuta" and "Steam Locomotive Train" (SL), of length 300 frames (5 sec) each, plus one additional frame appended at the end containing a copyright notice (and the coding process for experiments should not include that frame).

Coding PSNR results for AI HE, RA HE, AI LC, and RA LC were provided.

It was remarked that these sequences were produced using upsampling from a Bayer-like RGBG capture that was not full resolution for all color components. It was suggested that, in the longer term, true 8K sequences (not upsampled) would be desirable to obtain to avoid potential effects from the upsampling filter.

The original sequences were 10 bits per sample. After the upsampling, fixed rounding was applied to convert to 8 bits per sample.

We currently have two Class A sequences in our common test conditions. Adding these would bring that to a total of four.

It was noted that the lower number of sequences in Class A relative to other classes has, up to now, resulted in Class A being under-represented in overall averages.

It was remarked that the Nebuta sequence contains a significant amount of noise.

It was remarked that the HE configuration actually processes video using 10 bits per sample. However, it does not operate in a 4:4:4 mode.

The contributor can provide the 10 bit per sample sequences.

Planar formatting for the input and output files (probably 16 b per sample, aligned to MSB or LSB? Which endian? – check the JM) was expected to be used to accommodate the 4:2:0 nature.

The usual Hannover ftp site should work for distribution.

Decision: These sequences are adopted into our Class A common test conditions (as additional sequences not replacing either of the two prior ones), using the 10 b version for the HE case. These sequences were uploaded to the BBC server during the meeting, and 8b sequences had previously been uploaded to the Hannover server. The BBC server has also been used for reference encoding bitstreams.

Participants may contact the JCT-VC or test material AHG chairs to obtain access credentials for the sequences.

JCTVC-D092 Study on coding performance of HM1 with new test sequences [Teruhiko Suzuki, Ali Tabatabai]

As JCTVC-C168 advocated, it was asserted to be important to test a greater variety of test materials during the development of HEVC. The current test sequences were reported to be similar to each other in some characteristics. For example, a lot of panning sequences are included. It was suggested that new test materials to cover a larger variety of scenes should be collected. This contribution reported the coding performance of existing test materials of VCEG/MPEG. The coding performance was compared with AVC High profile by JM 17.2.

ParkJoy, Crowd Run, and (to a somewhat lesser extent) Night were noted to be especially difficult. It was noted that the graphs in the contribution (v2) had some labeling problems. It was noted that the chroma performance is sometimes not good relative to the JM, and perhaps we should study the default balance between luma and chroma fidelity and perhaps align that more closely to the AVC standard.

It was proposed to include Crowd Run in class B and to include Night and Harbor in Class E (or create a new Class F).

However, the group thought that it may be best not to take that action (at least at this time). Some specific aspects of the discussion are noted below.

It was remarked that Crowd Run (and other SVT sequences such as Park Joy) have very high noise due to being captured with an early capture process (involving conversion from 50 Hz film capture).

It was remarked that Night and Harbor were compressed in the original (using D5) and have some (visually minor but possibly relevant) artifacts as a result.

It was remarked that we should not select sequences just because they provide worst-case results relative to AVC. In fact, it would be undesirable to do so, as this would produce a test set that under-represented the coding capability of HEVC for typical use.

"People on Street" in Class A (and the new Nebuta) was noted to also be noisy.

It was remarked that VQEG has a large number of new HD sequences (and are producing additional ones), and investigation of the use of these may be beneficial.

It was suggested that the Test Material AHG should be continued.

JCTVC-D252 Test Material for Screen Content coding [W. Ding, Y. Shi, B. Yin (BJUT)]

This contribution described and introduced a set of test sequences for screen content which were offered to be made available to JCT-VC and parent bodies by Beijing University of Technology. BJUT proposed to adopt these sequences for developing and testing JCT-VC standards. These were provided in YUV 4:2:0 format. They are further described in the tables below:

Characteristics of test sequences of screen content

Sequence	Resolution	Frames	Frame rate fps	Chrome format	Bit-depth Per Sample
Doc	1280x800	400	10	4:2:0	8
Gaming	800x600	500	50	4:2:0	8
Slide	1280x800	500	20	4:2:0	8
Web	1280x800	500	25	4:2:0	8

Scene content description of screen content test sequences

Sequence	Brief Description
Doc	A word document is being edited.
Gaming	A flash game playing with moving objects.
Slide	A slide show with all kinds of animations.
Web	Web browsing activities.

A participant remarked that current typical screen content characteristics may use higher resolution than these.

A participant remarked that higher frame rates may be desirable.

A participant requested for 4:4:4 versions to also be made available (which the contributor said they actually already had and could easily provide it within a few days).

TV content with graphics overlays was also suggested to be a valuable type of material to collect for the "screen content" category.

The suggestion was made to create a "Class F" from this content, but Class F would be optional for experiment reporting and would not ordinarily be included in common conditions reported averages for the usual cases (I, RA, and LD for HE and LC).

This suggestion was supported by the group.

It was remarked that it is necessary to ensure that there are no third-party content rights to the content that was captured in the scenes. Any sequences for which some problem is identified in that regard must not included in the Class F testing set.

BoG activity coordinated by O. Au, J. Xu, and H. Yu was requested to further discuss and propose mandates for AHG activity. (See BoG report JCTVC-D458.)

Further work was encouraged (in AHG) to improve the content available for this type of testing.

17.4 Application-Specific Topics

JCTVC-D054 Benefit of the new syntax and semantics for very low delay coding in HEVC [Kimihiko Kazui, Junpei Koyama, Akira Nakagawa]

A scheme was proposed which reportedly minimizes the loss of coding efficiency in very low delay coding (delay of less than one frame period) at the 2nd JCT-VC meeting. Further, a low-delay buffer model was proposed at the 3rd JCT-VC meeting. This contribution describes the feature and asserted benefits.

Very low delay, in this contribution, is based on a model with small buffers that should not overflow or underflow.

A vertical intra macroblock line refresh scheme (with a vertical position shifted from frame to frame) allows recovery in case of losses; pixels in a refreshed area should not refer to pixels in the not-refreshed area. Deblocking should be disabled at the MB boundary of the refreshed area (similar concepts as for slice boundary).

At the encoder side, constraints are imposed that guarantee that no references are taken to non-refreshed areas. This certainly imposes some penalty in compression capability, and JCTVC-C021 reports approximately 9% loss.

JCTVC-D053 Draft description of proposed syntax and semantics for very low delay coding (Kimihiko Kazui, Junpei Koyama, Akira Nakagawa)

This proposed scheme is intended to minimize the loss of coding efficiency in very low delay coding of less than one frame period. The details of the proposed high-level syntax and semantics are described in this contribution. The details of the new buffer model as proposed at the 3rd meeting were also described.

Syntax for region based refresh (flag in slice header, refresh direction and boundary position; SEI syntax for buffering period) was discussed.

The main purpose is random access refresh, not robustness to data losses.

JCTVC-D052 Updated evaluation result of proposed syntax and semantics for very low delay coding [Kimihiko Kazui, Junpei Koyama, Akira Nakagawa]

This contribution reported additional test results of a proposed scheme for very low delay coding with delay of less than 1 frame period, compared with another possible scheme based on AVC.

The software used for this test was based on TMuC 0.9.

The reported coding gain is 6.0% (64x64 LCU) and 6.3% (32x32 LCU).

JCTVC-D052, JCTVC-D053, and JCTVC-D054 were presented together.

In JCTVC-D052, the benefit is shown relative to a method that disable the loop and deblocking filters globally. It was suggested to also compare against a scheme where the filter is switched on (i.e. a little bit of drift would occur, which may not be too severe as it is due to spatial filtering). In that case, this would not imply normative changes and an SEI message would be sufficient.

In general, this work is highly related to slice approaches.

JCTVC-D073 Periodic inits for wavefront coding functionality [K. Misra, A. Segall]

This contribution proposed a method for initializing CABAC at the start of each largest coding unit (LCU) row. The primary goal of this proposal was to create a bitstream that is friendly to parallel "wavefront" encoding and decoding, while allowing LCUs to be written in raster-scan order in the VCL. It was asserted that a very high degree of parallelism (e.g., 16x for 1080p) can be achieved with a BD bit rate increase of 0.2% for intra, 1.3% for random access, and 1.6% for low delay scenarios. The impact is due to context re-initialization and also signaling the entry points within the bitstream. If the entry points are instead signaled using markers, then the BD bit rate increase was reported as 0.2% for intra, 1.8% for random access and 2.3% for low delay. If no entry point information is communicated, then the BD bit rate increase is reportedly 0.1% for intra, 1.1% for random access and 1.2% for low delay.

Further study of this was encouraged in the context of a slice AHG.

JCTVC-D178 Impact of cascaded coding on HEVC [A. Gabriellini, D. Flynn, T. Davies]

This contribution explored the impact of cascaded coding on the performance of HEVC, where the prior coding is asserted to be representative of that typically used for high-end capture and playout in broadcast systems. JM 16.2 is used as an anchor reference to evaluate the coding performance of HM 0.9 when fed both processed and unprocessed class B pictures. HM, in its default configuration, reportedly demonstrates very good performance when applied to processed material, with a larger BD BR gain than for unprocessed pictures. A second test was reported to show the importance of the adaptive loop filter (ALF) in ensuring the positive results highlighted by the first test. The comparison between the HM with and without ALF, with both sets of inputs (pristine and processed material) reportedly shows that the BD BR increase for HM with ALF is 2.0% higher for Random Access when the input material has coding artefacts.

Compression is often used in cameras and post production; it is very likely that HEVC will need to compress material that has been compressed before.

It was reported that performance is better for precompressed material than for uncompressed material (about 3-4%); it was also found that ALF provides even more gain in the case of precompressed material.

The reference was not the same, i.e. in the case of precompressed PSNR, this was computed relative to the precompressed "original".

It is suggested in the contribution to check performance from time to time with compressed material. This was not fully agreed in general as being important because the compression may have a "simplifying" effect similar to denoising and lowpass filtering.

In general it is good to hear that operation on (lightly) compressed sequences does not necessarily affect the performance of HEVC.

JCTVC-D202 1:2 Spatial Scalability Support for HEVC [D. Hong, J. Boyce, A. Eleftheriadis (Vidyo)]

SVC as standardized has been shown to enable efficient and robust videoconferencing systems, utilizing temporal and spatial scalability. This contribution proposes that the HEVC design be extended to incorporate a set of tools from SVC for supporting 1:2 spatial scalability. Including scalability tools in the initial phase of HEVC reportedly would enable a cleaner design, avoiding the need to retrofit the system design with "ugly" backwards-compatible patches, such as the NAL unit header SVC extension and the prefix NAL unit. This contribution restricts spatial scalability support to 1:2 for simplicity and because of its usefulness in currently deployed applications. Although 1:2 spatial scalability support for I, P and B pictures is described, because of time constraints, experimental results are only available for I pictures. In the high-efficiency setting, 2-layer AI scalable coding reportedly yields an average of (14.9%, 17.7%, 17.3%) (Y, Cb, Cr) BD BR gain and a maximum of (29.8%, 33.7%, 35.4%) BD BR gain over simulcast. In the low-complexity setting, 2-layer intra only scalable coding yields an average of (13.7%, 16.7%, 16.6%) BD BR gain and a maximum of (27.4%, 31.9%, 32.3%) BD BR gain over simulcast.

- Temporal scalability is already supported in the WD
- Spatial scalability 1:2 was proposed with Intra prediction, motion prediction, and residual prediction
- For upsampling, the same filters are suggested as in AVC – how about using HEVC interpolation filters?
- Implemented so far only for intra

- The proponent emphasized their view that scalability should be in the first phase

Comments:

- Several experts support the idea
- Limiting to 1:2? Other ratios could be interesting.
- Some concern was expressed that we have many other issues of higher priority
- The current solution is on average 19% higher rate than single layer coding (for intra only). For the intra only case, AVC-SVC is usually relatively close to single-layer. In HEVC, the coding performance of the combination of layers is likely to be due to the fact that a larger amount of bits is spent for mode information, which likely makes the HEVC scenario more tricky. In the reported implementation of 1:2 spatial scalability, an LCU of 64x64 was used for both the base and enhancement layers, with no dependency of the modes between the two layers.
- For inter, this may be even more difficult.
- It should not affect the timeline.
- To assess the situation, it might be interesting to compare how, for the same sequences (intra only), the gap between AVC single layer and AVC-SVC is compared against HEVC single-layer / "HEVC-SVC".
- Further study in AHG was encouraged – including investigation of what "hooks" need to be provided in HL syntax and what are the benefits of current "simple" solutions (including inter cases).

17.5 Loop Filtering

JCTVC-D039 ALF decode complexity analysis and reduction [M. Budagavi, V. Sze, M. Zhou (TI)]

This contribution analyzes implementation the complexity of the Adaptive loop filter (ALF) at the decoder.

The contribution only studies the luma filtering.

The current filter allows up to 16 luma filters to be selected per slice, with support regions up to 9x9 diamond.

It was remarked that the symmetry property of the current filter kernels seems unusual and questionable, and may be the result of testing performance on our training set (although the tests sets have changed since that design decision was made) or of raster-flow decision-making processes. It was remarked that enforcing quadrant symmetry does seem to cause some loss in performance (although we don't know how much).

Implementation complexity analysis involves not just analysis of computations but also analysis of memory bandwidth and memory size (area).

There are reportedly two ways to implement ALF at the decoder – frame-based filtering and LCU-based filtering. For both frame-based and LCU-based filtering, line buffers that store previous lines of the deblocked image are needed to reduce memory bandwidth requirements. LCU-based filtering was suggested to be preferable.

The vertical extent of the filter was indicated to be especially important.

This contribution presents two ALF filter sets that reduce the vertical size of the filter – thereby reducing the line buffer/memory bandwidth requirements. Both filter sets have a maximum vertical extent of 5 lines. Filter set 1 reportedly reduces memory bandwidth/memory size requirements by 50% and worst case computations by 20%. Filter set 2 reportedly has similar computational complexity as the existing HM ALF filters but reduces memory bandwidth/memory size requirements by 50%. Existing HM ALF filters reportedly provide average BD BR savings in range of 3.3%-4.1%. Filter set 1 and set 2 provide average BD BR savings in the range of 3.2%-4%.

The Nx5-Set2 filter support scheme was reportedly cross-checked in JCTVC-D188.

The proponent indicated a preference for the proposed "Nx5-Set1" variant, and this view had some support.

A participant remarked that rapid adoption without examining chroma might be a bit of an ad hoc way to move forward, such that perhaps we should do further study instead.

Another participant remarked that the Nx7 approach would be a conservative way to embrace this concept with minimal short-term impact on performance.

Decision: Adopted "Nx7" variation.

JCTVC-D188 In-loop and post-processing filtering AHG: Verification results of TI's Proposal JCTVC-D039 [T. Yamakage, T. Chujoh (Toshiba)]

Cross-check of JCTVC-D039. The verification only checked "Nx5-Set2", but included studying the software as well as its results.

JCTVC-D116 Region-based adaptive loop filter using two-dimensional feature [T. Ikai, Yukinobu Yasugi (Sharp)]

In this contribution, a region-based adaptive loop filter using two-dimensional feature was proposed. In the proposal, a hierarchical region division was proposed using two-dimensional features: activity and direction.

In the proposed technique, up to eighteen sets of filter coefficients can be sent. The technique was reported to be compatible with the DF-combined ALF where the number of input signals is two.

The experimental results reportedly show that the proposed technique using one input provides 0.5% BR reduction for HE and that the two input scheme (with DF-combined ALF) provides 1.4% BR reduction compared with the anchor (QC_ALF).

The scheme is primarily for inter coded areas. There was only 0.1% gain shown for AI HE.

The adaptivity in the proposal operates on a 4x4 region basis, and the proponent indicated that this aspect is better than the sample-by-sample adaptivity in the current reference design.

No cross-verification was provided.

Further study was encouraged.

JCTVC-D213 In-loop reference frame denoising in HEVC reference software [Peter Amon, Eugen Wige, Andreas Hutter, André Kaup]

This proposal presents an algorithm for in-loop denoising of the reference frame. The algorithm modifies the temporal predictor while the decoded picture is unchanged. Knowledge of the noise power within the reference frame is used in order to improve the inter frame prediction. For noise filtering of the reference frame, a denoising algorithm is implemented. In JCT-VC219, the results for the implementation of the algorithm in the AVC reference software (JM 15.1) were presented. It was reportedly shown that the BR can be decreased for (high resolution) noisy image sequences, especially for higher qualities at medium to high data-rates. This contribution reportedly shows that the gains are nearly preserved when implementing the scheme in the HEVC reference software (HM 0.9) for coding of the similar test material. In addition, results for coding two sequences of the standard test set for HEVC are shown.

It was remarked that since this proposes a different processing for the picture that is output than for the picture that is stored for reference purposes, the storage requirements for out-of-order decoding would likely be increased (in the present form of the proposal).

The experiment results were provided for different sequences than are used in the common conditions (only two of the current common conditions test sequences were tested).

The testing was performed for the LD HE case.

The gain shown in the experiments was primarily at high coding fidelities. Compression impacts were reported that ranged from 0.7% (or more) degradation to 3.2% improvement, depending on the sequence. Theoretically, degradations should not be observed with ideal use of the concept.

It was remarked that current broadcast encoders perform some denoising of video source material prior to encoding, which may affect the result obtained by such methods.

Currently, the tested method does not use syntax – only decoder-side inference of the filter to be applied is performed.

This work was reported at a rather preliminary stage of maturity, although it was beneficial to see that progress had been made on moving the technique into the group's common software for testing in that context.

Further study was encouraged.

JCTVC-D385 Adaptive Loop Filtering Using Multiple Filter Shapes [F. Kossentini, N. Mahdi, H. Guermazi, M. A. BenAyed (eBrisk Video Inc)]

This contribution presents the advantages of utilizing different filter shapes in the Adaptive Loop Filtering (ALF) part (only the ALF part that is applied to the luminance samples) of the TMuC 0.9 encoder/decoder. More specifically, it was reported that the simultaneous use of 7x7 diamond-shaped and 13x13 cross-shaped filters yields both an improvement in coding efficiency and a reduction in decoder complexity.

A 40% decrease in the worst-case number of multiplies and adds was reported.

Approximately 10% decoder runtime decrease was observed.

Some testing was reported for reduced vertical extent (reduced to 7 or 9 samples vertically).

Encoding time somewhat increased, but encoding was asserted to be parallel-friendly.

Results were reported as follows: HE LD 0.9% improvement, RA 0.4% improvement, AI 0.1% degradation (from reduced worst-case filter region of support).

It was remarked that the filter on/off decision method was more complex in this proposal, since in the HM the decision of on/off is always made for 5x5 rather than testing the results of different filters to make this decision.

A participant remarked that the lack of full 2D support in the cross-shaped filter design might produce visual artifacts.

No cross-verification was provided.

Further study was encouraged.

JCTVC-D221 Loop filter with directional similarity mapping (DSM) [P. Lai, F. C. Fernandes (Samsung)]

This contribution presented an adaptive loop filtering design which combines linear spatial filtering and a directional "similarity filter" with a mapping function. To suppress ringing artifacts and preserve edges, the filters exploit directional features in video frames, and the mapping function avoids using pixels with large differences from the pixel to be filtered. The filter design uses only 4 filters with up to 7x7 window size. Using TMuC 0.9 with no ALF as anchor, experimental results reportedly demonstrate average BD rate reductions of 3.5% and 3.3% for Inra HE and Random Access HE, respectively. As compared to the ALF in TMuC 0.9, lower encoding complexity (135% to 118% for Intra HE against anchor) and improvements in visual quality around edges were reported in the Intra and RA settings.

The goals are to reduce computational complexity and to improve visual quality near edges.

Filter symmetries are designed to match the directional filtering classifications.

It was remarked that this may provide perceptual benefits, and that the perceptual effects should be studied.

The report for the technique was somewhat preliminary.

No control map was used.

No cross-verification was provided.

Further study was encouraged.

JCTVC-D270 Low Complexity Parametric Adaptive Loop Filter [E. Maani, W. Liu, L. Dong (Sony)]

This contribution proposes a type of Adaptive Loop Filter (ALF) intended to remove coding errors and improve compression efficiency. In this approach, a set of fixed filters was used instead of the traditional trained Wiener filters. The encoder chooses the best (in an RD sense) filter for a Coding Unit (CU) and transmits the index of the filter to the decoder within the bitstream. The selection of the filter at the encoder uses a single pass processing for each LCU, thereby reportedly reducing the encoder delay significantly compared to traditional ALF approaches which were asserted to require one frame delay.

A participant asked whether the common conditions sequences had been used for the training of the filter tap values. The presenter said that additional sequences were used, but he was unsure whether any of the common conditions sequences had been used.

The results were only shown for the LC cases (in which ALF is disabled).

Results were reported as follows: AI LC: 2.3% improvement, RA LC: 2.5% improvement, LD LC: 3.9% improvement.

Further study was encouraged (e.g., in CE).

JCTVC-D406 Cross-verification of SONY's proposal on low complexity parametric adaptive loop filter (JCTVC-D270) [Minhua Zhou] (missing prior, uploaded Monday 17th, before meeting)

Cross-verification of JCTVC-D270.

This contribution also provided results for use with ALF enabled. A 3.1% loss was reported in the RA case (with 20% decoding time reduction). Decoding time was reportedly reduced.

It was reported that the proposed parametric adaptive loop filter algorithm has the potential of improving the coding efficiency and reducing the encoder-side complexity; however, its decoder complexity deserves further investigation. The large number of pre-defined wiener filters (i.e. 32 9x9, 32 5x5), longer filter tap length (i.e. 41 tap and 25 tap), and higher precision of filter coefficients (i.e. 18 bits) could reportedly make the PALF more expensive than the HM1 ALF on the decoder side. The contributor recommended to carry out CEs on the ALF proposals including the PALF to seek a new ALF design which addresses the both encoder and decoder ALF complexity concerns raised in the various contributions.

JCTVC-D377 Development of HEVC deblocking filter [A. Norkin, K. Andersson, R. Sjöberg (Ericsson)]

This contribution proposed a deblocking filter developed from the current HEVC deblocking filter. The proposed filter reportedly outperforms the TMuC0.9 anchor for all six common test configurations, with an average BD BR reduction of 1.2%. The decoding time is approximately unaffected. The subjective performance of the proposal was reportedly similar to that of the anchor.

Considers application of different modifications on each side of an edge.

The proposed changes reportedly do not modify the current deblocking framework.

Less filtering is conducted for smaller blocks (modifying only 1 sample on each side of the boundary). The smallest filtered block boundaries are still 8x8.

Some table values were also modified.

JCTVC-D192 Analysis on the interaction between deblocking filtering and in-loop filtering [T. Yamakage, S. Asaka, A. Tanizawa, T. Watanabe, T. Chujoh (Toshiba)]

This contribution reports some analysis on the relationship for various in-loop filtering techniques, in particular interaction between deblocking filtering and Wiener-based in-loop filtering (QC_ALF). This item was one of the mandates of the In-loop and post-processing filtering ad-hoc group.

In this contribution, a parameter (β) that controls filter on/off and strength of filtering for deblocking was adjusted (thus weakening the filtering) for both with and without QC_ALF cases. By comparing the BD BR gain of each case with the best performing β values, QC_ALF reportedly showed additional BR reduction of 0.7% for AI, 0.5% for RA and 0.7% for LD case for HE coding condition.

The contribution advocated changing the β values for deblocking filtering according to the usage of QC_ALF so that the default value can provide the best performance.

The presenter noted that excessive weakening of the filter might occur if we exclusively optimize the parameters for PSNR performance. The subjective effect of the filtering very important.

JCTVC-D293 Toshiba : Crosscheck of Toshiba's deblocking filter in JCTVC-D192 by MediaTek [Jicheng An, Xun Guo]

Cross-verification of JCTVC-D192.

JCTVC-D214 Reduction of operations in the critical path of the deblocking filter [Matthias Narroschke, Hisao Sasai, Thomas Wedi]

In the current HM, the deblocking of images is performed based on CUs. For the deblocking of a current coding unit, it was proposed to perform all required decisions based on the unfiltered signal of the current coding unit. This removes dependencies present in the current deblocking filter design. The removed dependencies increase the parallel processing possibilities for the deblocking filter. As a consequence, the sequential operations required in the critical path for the decision and filtering operations of the deblocking filter were reduced – reportedly by 30%. The BD-BR stays unchanged for the luma signal and approximately unchanged for the chroma signals. An average BR reduction of 0.2% is reported for the two chroma signals in the case of LD HE and of 0.1% in the case of LD LC (up to 0.5% for certain classes). The effect on the subjective quality was reportedly not noticeable.

JCTVC-D455 Cross-check results of the deblocking filter of Panasonic (JCTVC-D214) [Teruhiko Suzuki, Masaru Ikeda] (late registration Wednesday 26th after start of meeting, uploaded Thursday 27th, near the end of the meeting)

No detailed discussion of this cross-check contribution was considered necessary.

JCTVC-D263 Parallel deblocking filter [Masaru Ikeda, Junichi Tanaka, Teruhiko Suzuki]

This contribution proposed a modification of the deblocking filter design in TMuC-0.9. First, the filter process is made parallel by changing the order of horizontal filtering (across vertical edge) and vertical filtering (across horizontal edge). Second, the edge judgment of the block boundary for the deblocking filter is made parallel by changing the position of the lines which are used for the judgment.

The contribution proposes to effectively perform all horizontal filtering before any vertical filtering.

It proposes to modify which lines are used in the decision of where to apply the filtering, to avoid having the first stage of filtering affect the second stage of filtering.

With the modifications, it is not necessary to perform the DF processing on a LCU-by-LCU basis. The decoder would obtain the same result with different ordering of the DF processing.

A slight loss in BD BR performance was reported – about 0.0-0.2% average, somewhat more in Class E.

The loss is primarily due to the modification of which lines are used for the filtering decisions.

JCTVC-D454 Cross-check results of the parallel deblocking filter of Sony (JCTVC-D263) [Matthias Narroschke (Panasonic)] (late registration Wednesday 26th after start of meeting, uploaded Thursday 27th, near the end of the meeting)

No detailed discussion was considered necessary.

JCTVC-D434 Cross verification of Ericsson's proposal JCTVC-D377 by Nokia [K.Ugur (Nokia)] (late registration Saturday 22nd after start of meeting, uploaded Saturday 22nd, third day of meeting)

Cross-verification of JCTVC-D377.

17.6 Block Structures and Partitioning

JCTVC-D087 Encoding complexity reduction by removal of NxN partition type [Jungsun Kim, Byeongmoon Jeon]

This contribution proposes removal of the NxN PU partition type for both inter and intra predicted CUs to reduce encoding complexity. In the current HM, a CU may split into several PU partitions. Two types of splitting and four types of splitting are used for intra and inter CUs, respectively. In the proposed methods, the NxN PU partitioning is prevented except when the CU has the maximum depth. The proposed scheme reportedly shows approximately 29% encoding time reduction with 0.2% loss in BD BR under the condition of intra high efficiency and 18% encoding time reduction with 0.3% loss in BD BR under the condition of random access high efficiency.

Corresponding losses for LC were 0.9% intra, 0.8% inter.

JCTVC-D432 Remove Partition Size NxN [S. Liu, Y.-W. Huang, S. Lei] (late registration Friday 21st after start of meeting, uploaded Friday 21st, second day of meeting)

This contribution proposes to remove the PU partition size NxN for both inter and intra CUs, for the purpose of removing encoding redundancies. Both inter and intra CU syntaxes are modified accordingly. Results reportedly show that with this modification the encoding time can be reduced by 20% and 30% for inter and intra, respectively, at 0.2% BD BR increase for HE.

Results were similar to JCTVC-D087 (slightly less loss reported)

It was noted that the loss is higher in LC case. The question was asked whether it would be better to set RQT depth = 2 to keep some of the performance.

For LC, LCEC was replaced by CABAC in LC, and it was found that the loss came to a similar range as for HE, so it was concluded that this is a problem of LCEC.

It was asked whether the same goal could be achieved by just modifying the encoder, while keeping the syntax unchanged.

Two experts expressed the opinion that, for the intra coding case, removing NxN mode for CU's larger than the minimum size may restrict some functionality (e.g. related to copying chroma modes from luma modes).

It was reported that by handling this as an encoder-only issue (i.e. retaining the syntax), the BR increase would be around additional 0.1% for HE and 0.5% LC case

Decision: Remove NxN for CU's larger than minimum size also for intra, for both HE and LC configurations.

The problem with LC mode should be further investigated.

Additionally, a request was made to remove the NxN partitioning for inter at the minimum CU level. Arguments are made against this – that it may be disadvantageous for high bit rates.

JCTVC-D060 Evaluation results on Residual Quad Tree (RQT) [Minhua Zhou, Ali Tabatabai]

This document reports evaluation results of the residual quadtree (RQT) adopted in the first version of the HEVC test model (HM1). When compared to two-level method used in TMuC-0.7, the RQT reportedly provides marginal gain in the luma component of high efficiency configurations, but reportedly leads to loss in other configurations, especially in the chroma component parts in which the significant loss was reported. The RQT performance with respect to encoder complexity was also discussed in this contribution. It was asserted that the current RQT design needs further improvement in regard to the complexity and coding efficiency performance as tested and recommended to set up an ad-hoc group for the development of improved TU tree representation methods which would simplify both the encoder and decoder design.

- Comparison was discussed of the RQT vs. the 2-level method from TMuC 0.7.
- HE: Gain in luma 0.5%, 0.4%, 0.1% AI/RA/LC; but loss in chroma
- LC: Loss in luma 0.3%, 0.6%, 0.9% AI/RA/LC; also loss in chroma
- The question is raised in the contribution whether an explicit TU tree is necessary.

Further study in an AHG was suggested.

JCTVC-D250 Efficient transform unit representation [Krit Panusopone, Xue Fang, Limin Wang]

This document proposes a modified transform unit representation. The proposed approach modifies the RQT based-TU partitioning scheme in the TMuC. The proposed syntax change offers a particular trade-off between coding efficiency and additional complexity.

It is proposed that maximum TU size be linked to PU size, instead of CU size and RQT be completely removed, i.e. for the TU size to always be the same as the PU size (or, for non-rectangle PUs, to have 2 TUs in the PU).

It was only suggested to apply this for inter, as the loss for intra would be too high (see TE12 from the third meeting).

Losses are reported as 0.9/0.9% BD increase for RA, and 1.0/1.8% for LD (HE/LC).

Encoding time was reportedly reduced to 75/90%.

- It was asked what would be the implications of the new decisions related to CE9 (JCTVC-D441).
- It was questioned whether it is good to give up the flexibility of TU splitting (either for TU spanning over PUs or for further splitting of PUs)

JCTVC-D433 Cross-check for Motorola Mobility's Proposal JCTVC-D250 on Efficient Transform Unit Representation by RIM [Jinwen Zan (RIM), Dake he (RIM)] (late registration Saturday 22nd after start of meeting, uploaded Saturday 22nd, third day of meeting)

JCTVC-D142 A unified design of RQT cbf coding in LCEC [B. Li (USTC), J. Xu (Microsoft), F. Wu (Microsoft), H. Li (USTC)]

In the TMuC 0.9, RQT is used to represent the residue. RQT is more flexible than a fixed number of transform levels. When representing the residue in RQT, besides the residue coefficients, the quad-tree structure and the cbf related to the quad-tree structure need to be signaled to the decoder. When LCEC is used, a combined coding of the cbf is used in the current TMuC. But in the current design, when max transform depth > 2, disabling the combined coding will reportedly get better results. This contribution presents a design for both max RQT depth = 2 and depth > 2, which has different performance for both cases. Compared with the reference configurations, it was asserted that the proposed method will improve the coding efficiency with no appreciable impact on complexity at both encoder and decoder side.

The split flag is coded as usual.

In the case of depth 2, there is negligible change.

In the case of depth 3, combined coding was disabled, as it reportedly works better. Compared to that, the reported gain is larger.

In discussion, the general question was asked wheter the restriction of 2 levels would be retained.

JCTVC-D375 LCEC coded block flag coding under residual quadtree [X. Wang, W.-J. Chien, M. Karczewicz (Qualcomm)]

This proposal presents a coding scheme for coded block flag under the residual quadtree structure. Based on the proposal, the current joint coding of Y, U and V coded block flag at CU root level is extended in two ways: 1) it further includes transform split flag if available; 2) The joint coding is not only performed at the CU root level, but also extended to a higher transform depth level so that the benefit of such joint coding can be maximized. Simulation results reportedly show that such extension of the joint coding can improve coding efficiency, especially when there are multiple levels of transform tree decomposition.

The current implementation of CBP coding under LCEC reportedly works well with a maximum TU depth level 1 and 2. When the maximum depth level is 3, the performance is reported not to be so good. Some investigation into the issue was reportedly done after release of TMuC 0.9 and it was reported that it is not because of the CBP signaling mechanism, but the RD not quite matching to CBP signaling. With changes in the RD function, the coding performance of the current CBP signaling under LCEC reportedly works well too for a maximum depth level of 3 or higher.

- RD fix reportedly gives 1.8/1.0/0.9% BR reduction in AI/RA/LD when 3 levels are enabled.
- The reference in the results shown is not the same.

The following approach was suggested for more efficient coding of CBP:

- Transform split flag is jointly coded together with coded block flags
- In addition to CU root level, the joint coding of coded block flag and transform split flag is also performed at higher transform depth level
- If only one coded block flag left in each block to be coded, the four flags at the same transform depth level are grouped and jointly coded as before

Decision: Adopt the bug fix (encoder only issue) – this would resolve the current warning message.

Further investigate in a CE (JCTVC-D142, JCTVC-D375) further improvements of 3-level configuration in LC,

JCTVC-D143 Results for redundancy reduction in PU-based merging [B. Li (USTC), J. Xu (Microsoft), F. Wu (Microsoft), H. Li (USTC)]

In JCTVC-C277, a method was proposed to reduce the motion vector candidates in CU/PU-based merging. This document studies the performance of such a method in PU-based merging with TMuC0.9.

When CU is SIZE_2NxN, SIZE_2NxnU or SIZE_2NxnD, the motion of the PU above a location cannot be a candidate for the PU below it. When CU is SIZE_Nx2N, SIZE_nLx2N or SIZE_nRx2N, the motion of the PU on the left cannot be a candidate of the PU to its right.

This change had been adopted according to JCTVC-D441.

JCTVC-D165 CU-level Directional Merge Mode [Jicheng An, Xun Guo, Yu-Wen Huang, Shawmin Lei]

In this contribution, a directional merge method is proposed to improve the CU-level merge mode in HM1.0. The syntaxes of two merge methods are the same. The contribution changes their semantics to use the motion information from more neighboring blocks to increase the chance of sharing motion parameters from neighboring blocks. Compared to the anchor of HM1.0, average bit rate reductions of 0.2%, 0.3%, 0.4 and 0.5% were reported for random access HE, random access LC, low delay HE and low delay LC, respectively. If compared to HM1.0 with merge mode off, the proposed method can reportedly achieve bit rate reductions of 0.8%, 0.2%, 1.2 and 1.6% for random access HE, random access LC, low delay HE, and low delay LC, respectively. There is reportedly essentially no increase in encoding time and decoding time for the proposed method.

Motion vectors from a row of blocks above or from a block of columns to the left are merged – with a reported increase of complexity being very small – several experts supported to further investigate this.

It was asked how it works with the new design (PU based merging)

Further study in CE9 was suggested.

JCTVC-D316 Crosscheck of MediaTek's Proposal JCTVC-D165 on CU-level Directional Merge Mode [B. Bross (Fraunhofer HHI)]

Results were confirmed and further study suggested

JCTVC-D249 Super large coding tree block [Krit Panusopone, Xue Fang, Limin Wang]

This document describes the concept of "super largest coding unit" (SLCU) to allow representation of largest coding unit (LCU) in a more efficient way. It was asserted that this reduces the overall quadtree overhead for high resolution video as well as the complexity for low resolution video.

An SLCU is proposed, consisting of 2x2 regular LCUs. The processing order is different from normal LCU order. The same split flat syntax is used for LCU and below in the coding structure. A split flat syntax is proposed for the SLCU level:

- Split flat '0' means all 4 CUs inside the SLCU use the LCU size, with no further bit transmitted.
- Split flag '1' means at least one of the 4 CUs use some sub LCU size, in which case more split flags follow.

LCU size 32 was used for classes C and D.

Results in 0.3%/0.4% BR increase, mostly from classes C and D, with encoder speedup by roughly 10%.

It was asked whether this speedup is mostly at low or high rates. Indeed the saving is reported to be mostly in classes C and D; when setting max CU size = 32, the saving would be marginal.

The benefit of the SLCU structure and associated syntax elements does not appear obvious.

17.7 *Motion Compensation and Interpolation Filters*

JCTVC-D138 Rounding control for chroma interpolation [B. Li (USTC), J. Xu (Microsoft), G. Sullivan (Microsoft), F. Wu (Microsoft), H. Li (USTC)]

The relevance of this document was affected by the planned change of the chroma motion interpolation filter to no longer use bilinear filtering. Further study was encouraged to determine whether the proposal could lead to an improvement in a future version.

A cross-check was provided in JCTVC-D310.

JCTVC-D175 Bi-prediction combining template and block motion compensations [C.-L. Lee, C.-C. Chen, Y.-W. Chen, M.-H. Wu, C.-H. Wu, W.-H. Peng, H.-M. Hang (NCTU/ITRI)]

This contribution proposed a bi-prediction scheme that combines motion vectors (MVs) found by template and block matchings based on parametric OBMC. Because the template MV is inferred on the decoder side, this technique only sends motion parameters for one block MV. The concept is further extended to allow the template MV to be replaced with one of the MVs for neighboring prediction units, enabling an implementation described as low-complexity and template-matching-free. Experiments were conducted using the TMuC-0.9_HM software and the common test configurations to evaluate three variants of this scheme. The best of them reportedly achieved an average BD BR saving of 2.2%, with a minimum of 1.4% and a maximum of 4.3%. It was reported that the average decoding time increased by 10% while the encoding time doubled.

Some significant gain appeared to be shown, and further study was encouraged (e.g., in a CE).

JCTVC-D225 Directional interpolation filters for luma samples using 8 filter coefficients [A. Fuldseth, G. Bjøntegaard (Cisco)]

This contribution relates to improving DIF using 8 tap filtering rather than 6 tap filtering. Due to the decision not to use DIF in the HM at this time, it was not discussed in detail.

For LC RA, an improvement of 2.4% was reported relative to the anchor.

For LC LD, an improvement of 2.6% was reported relative to the anchor.

JCTVC-D246 New interpolation filters [J. Lou, L. Wang (Motorola Mobility)] (missing prior, uploaded 20th, before meeting)

DCT-based interpolation filters and their low complexity optimization were reportedly introduced by Samsung in the current TMuC0.9. The 12tap DCT-IF has been used for the Low-Delay High Efficiency tests and the Random-Access High Efficiency tests. This contribution proposes different DCT-based interpolation filters. Compared to the current interpolation filters in the TMuC, better Rate-Distortion performance could reportedly be achieved with the same tap length, or lower complexity could be achieved with the same Rate-Distortion performance.

The proponent indicated that their proposal may provide some improvement in coding efficiency relative to the scheme planned for adoption at this meeting – e.g., 0.1-0.2% for 8-tap filtering. Some participants remarked that the 6 bit precision of the tap values for the adopted scheme was a beneficial property and that shift-add implementation should be considered.

Further study was encouraged (e.g., in a CE).

JCTVC-D266 Investigation on Luma Interpolation Filter [V. Sze, M. Zhou, M. Budagavi (TI)]

This proposal advocated the adoption of an 8 tap DCTIF MC interpolation filter, which had been agreed prior to its review, and therefore no detailed review of the contribution was necessary. The contribution advocated this action based on hardware and software complexity analysis (including memory bandwidth) and the amount of coding efficiency impact.

JCTVC-D285 Switching Interpolation Filter (SIF) scheme with low-complexity decision algorithm [T. Yoshino, S. Naito (KDDI)]

In the previous meeting, a Switching Interpolation Filter (SIF) approach was proposed to improve coding efficiency. However, the SIF approach with selecting the best filter based on RDO reportedly requires a significant computational cost. In this contribution, a different approach for determining filter coefficients was described, and the coding performance of the proposed SIF scheme with the modified filter decision was discussed. An 8-tap filter framework was employed to evaluate the performance under HE operation. The experimental results reportedly showed BD BR Y to improve 0.4% on average against TMuC0.9 under LD/LC condition while maintaining the encoding/decoding time to be approximately unaffected.

It was noted that the modification of the LC configuration motion interpolation already planned for adoption at this meeting would provide some benefit.

The proponent suggested that the possibility to select from several candidate filters may provide further improvement, although some modification of this proposal would likely be needed to achieve an improvement relative to the new anchor. Further study may result in a new method to provide additional gain.

JCTVC-D321 High precision bi-directional averaging [K. Ugur, J. Lainema, A. Hallapuro (Nokia)]

The current low complexity configuration includes rounding control for bi-prediction to combat the rounding error accumulation happening in averaging two predictions. This proposal argues that the error accumulation problem actually doesn't exist if the rounding operation for a bi-predictive signal is performed at the last step. After interpolating each one of the predictions, this proposal postpones some or all of the rounding to be after both predictions are added, while keeping all the intermediate calculations in 16-bits and does not use the "rounding control" scheme.

It was remarked that some clipping is also needed, and it was asked whether the clipping should be before or after the addition. The tested usage was to clip before the addition.

The decoding time reportedly increased by approximately 5%, which was described as being a consequence of the way some of the processing was implemented in the HM software rather than an intrinsic consequence of the proposed method. It was reported that the software might actually run faster if this part of the processing were changed.

It was noted that in AVC, weighted prediction is another way to introduce an offset in the decoding process.

The proponent indicated that, if used, the technique should be applied to chroma as well as luma.

Decision: Adopted into the HM.

JCTVC-D352 High accuracy averaging for bi-prediction (Verification of JCTVC-D321) [F. Bossen, S. Kanumuri (DOCOMO USA Labs)]

Cross-verification of JCTVC-D352 with some additional information provided. Careful study and analysis of the proposal was reported, as well as checking of results.

JCTVC-D397 A New Adaptive Interpolation Filtering Technique [F. Kossentini, N. Mahdi, M. A. Ben Ayed (eBrisk Video Inc)]

In this contribution, an Adaptive Interpolation Filtering (AIF) technique using adaptive filters was proposed for interpolation filtering of the luma samples of video sequences. The proposed technique allows the encoder to switch, for each of the three groups of positions, between the TMuC 0.9 fixed filter (12-tap and 6-tap for High Efficiency and Low Complexity profiles, respectively) and a newly-generated AIF filter. Compared to the TMuC 0.9, the proposed technique yields average BD BR reductions of 0.6%-0.9% for the two Low Delay configurations and the Random Access / Low-Complexity configuration.

12 tap filters were used for the HE case.

6 tap filters were used for the LC case.

The encoder selects, on a frame basis, whether to use the built-in fixed filters or to use tap values that are transmitted by syntax.

The fractional positions are classified into categories, and the encoder can indicate to use the built-in filters for some categories and transmitted filters for the others.

A coding efficiency improvement of 0.6-0.9% was reported for both the HE and LC cases.

The reported results were not complete.

The encoding times in these experiments were increased.

The proponent indicated that it would be possible to constrain the add/shift complexity of the custom filters.

Further study was encouraged (e.g., in a CE).

JCTVC-D438 Directional interpolation filter: alternative directions for f, i, k, q [Hongbo Zhu] (late registration Saturday 22nd after start of meeting, uploaded Monday 24th, fifth day of meeting)

This contribution presents alternative directional interpolation filter for sub-pel positions referred to as f, i, k and q.

A reduction of number of operations compared to the DIF in previous HM is reported, and the change in compression performance is said to be negligible.

After the decision made in CE3 (to use a unified interpolation filter, DCTIF-8tap) this proposal appeared not to need further consideration.

17.8 Motion Vector Coding

JCTVC-D055 Scalable motion vector competition and simplified MVP calculation [M. Zhou (TI)]

There were two parts in this proposal.

The first aspect proposed reducing the number of candidates for "motion vector competition".

As motion vector competition with five candidates reportedly significantly increases the complexity for motion estimation, this contribution recommended to add the option of motion vector competition with two candidates to enable high efficiency encoder design with lower complexity. The calculation of the left and upper spatial MVP candidates in the current HEVC design, which use to up 16 neighboring PUs, was asserted to be unnecessarily complicated, and it was recommended to simplify the design and use only up to two neighboring PUs in the calculation.

The average impact of this complexity reduction was reported to be in the range of 0.1-1.0% in degradation of BD BR performance.

It was noted that Class E had unusual behavior for this proposal – actually showing gain while the other classes showed losses. This could hypothetically be due to the characteristics of the source video – perhaps due to the effectiveness of temporal MV prediction in that case – or perhaps from pre-compression artifacts in these sequences.

Since the reference for comparison has changed, and some simplification of candidates was already planned, further study of this modification (or something similar to it) should be conducted prior to additional action. Further study was encouraged (e.g., in a CE).

The second aspect proposed a simplification for left/upper MVP calculation.

A simplification for the left/upper MVP was proposed and it was reported that this simplification had approximately no impact on coding efficiency (or a small gain). Up to 16 candidates are used in the current design, while the proposed simplification uses only up to 2 neighboring PUs.

It was remarked that some other contributions are also relevant to this discussion.

Further study was recommended (e.g., in a CE).

JCTVC-D331 Cross verification on scalable motion vector competition and simplified MVP calculation (JCTVC-D055) from TI [I.-K. Kim, T. Lee (Samsung)]

Cross-check of JCTVC-D055.

JCTVC-D095 Improvements on median motion vectors of AMVP [J. Park, S. Park, B. Jeon, W.-J. Chien, M. Karczewicz]

This contribution presented a method using median motion vectors (MVs) for Advanced Motion Vector Prediction (AMVP). In AMVP, MVs with the same reference index and same reference list are considered among spatial neighboring MVs. But in the proposed method, MVs with a different reference index or a different reference list are also considered. The first available MV is chosen with pre-determined order, and it is scaled and inverted as necessary according to temporal distances and prediction directions. It is then used to calculate median MV predictors. No gain was shown for LD configurations. The simulation results reportedly show that the proposed method achieves 0.4% and 0.5% bit rate reduction under random access high efficiency (RA HE) and random access low complexity (RA LC) configurations on average. For RA HE and RA LC, the encoding runtimes are 100% and 98%, and the decoding runtimes are 100% and 103%, respectively (i.e., approximately no impact).

It was remarked that in the current common conditions, only one reference frame is used for each prediction list in RA.

The vector scaling involves some added complexity.

It was remarked that for the temporal MV candidate, a scaling is already being applied.

Further study was recommended (e.g., in a CE).

JCTVC-D136 Crosscheck of LG and Qualcomm's Improvements on Median Motion Vectors of AMVP by MediaTek [Ching-Yeh Chen, Jian-Liang Lin, Yu-Wen Huang]

Cross-check of JCTVC-D095.

JCTVC-D125 Improved Advanced Motion Vector Prediction [J.-L. Lin, Y.-P. Tsai, Y.-W. Huang, S. Lei (MediaTek)]

This contribution describes a MediaTek proposal on improving the advanced motion vector prediction (AMVP) in the HM. Four changes to AMVP were proposed:

- First, in general cases, six spatial motion vector prediction (MVP) candidates and four temporal MVP candidates are used in the MVP candidate set for motion vector competition (MVC); in low complexity configurations, when the picture order count (POC) difference between the current picture and the co-located picture is equal to 1 and the co-located MV exists, the MVP candidates are reduced to one spatial MVP candidate and four temporal MVP candidates.
- Second, the order of the co-located temporal MVP is modified according to the POC difference.
- Next, when each spatial MVP candidate is derived, a predefined priority is used to select one motion vector (MV) from list 0 and list 1 MVs of the spatial neighboring block, and the chosen MV is scaled to the same reference picture of the current prediction unit (PU) as the spatial MVP candidate for MVC.

- Last, when each temporal MVP candidate is derived, a predefined priority is used to select one MV from list 0 and list 1 MVs of two co-located blocks, and the chosen MV is scaled to the same reference picture of the current PU as the temporal MVP candidate for MVC.

The modified AMVP can reported improve coding efficiency with roughly the same encoding or decoding complexity. When compared with the anchor in JCTVC-C500, the proposal can reportedly achieve 2.1%, 2.0%, 1.5%, and 1.0% BR reductions for high efficiency random access (HE-RA), low complexity random access (LC-RA), high efficiency low delay (HE-LD), and low complexity low delay (LC-LD), respectively. For HE-RA, LC-RA, HE-LD, and LC-LD, the average encoding times were reported as 98%, 99%, 95%, and 97%, and the average decoding times were reported as 100%, 104%, 101%, and 104%, respectively.

Cross-checks are in JCTVC-D096 and JCTVC-D333.

Some concern was expressed that proposals in this area may be affected by the increased number of reference pictures to be considered as a result of our adoption of JCTVC-D356.

Further study was encouraged (e.g., in a CE), including analysis of individual aspects and trying to find a way to minimize complexity while achieving improved coding efficiency.

JCTVC-D096 Cross-verification results of MediaTek's improved AMVP (JCTVC-D125) by LG [Joonyoung Park, Seungwook Park, Byeongmoon Jeon]

Cross-verification of JCTVC-D125.

JCTVC-D333 Cross verification on Improved AMVP (JCTVC-D125) from MediaTek [I.-K. Kim, T. Lee (Samsung)]

Cross-verification of JCTVC-D125.

JCTVC-D303 Consideration on AMVP [Kazushi Sato] (initial version rejected as a placeholder upload)

Already effectively addressed in CE9 context.

JCTVC-D428 Cross-check report of Sony's proposal JCTVC-D303 by Panasonic [Toshiyasu Sugio, Takahiro Nishi (Panasonic)] (late registration Thursday 20th after start of meeting, uploaded Thursday 20th, first day of meeting)

Cross-verification of JCTVC-D303.

JCTVC-D417 Cross-check report of Sony's AMVP modification (JCTVC-D303) [Tomoyuki Yamamoto, Yukinobu Yasugi (SHARP)] (late registration Tuesday 18th, uploaded Friday 21st, second day of meeting)

Cross-verification of JCTVC-D303.

JCTVC-D164 Temporal MV predictor modification for MV-Comp, Skip, Direct and Merge scheme [J. Jung, G. Clare (Orange FT)]

The current version of the HM includes temporal motion vector prediction through the Inter, the Skip and the Direct modes. The temporal predictor is mapping the origin of the block to a co-located block in another frame. In this contribution, two different temporal predictors are proposed. The first one is based on the computation of the median of the motion vectors of the co-located block, while the second one maps the center of the co-located blocks to the reference frame. For the latter, an average gain for each configuration with negligible complexity increase and no syntax change was reported.

Two modified temporal predictors were proposed. The first one, Tmed, reportedly shows an improvement for each configuration, from 0.9% for RA HE to 0.1% for LD LC. The second one, Tctr, reportedly shows similar gains, with no impact on the complexity compared to the current temporal predictor. Tctr has reportedly been tested with the "3.1.e" configuration from CE9, and reportedly improves the gain of this configuration. It is reportedly not dedicated to a specific configuration but intended to help any configuration that has a temporal predictor. In addition, using Tctr does not change the syntax of the standard draft.

The proponent recommended adopting Tctr has the new temporal predictor, whatever the mode (Inter, Skip, Direct, or Merge).

A participant indicated that one of the methods is similar (or the same) as JCTVC-D095 and JCTVC-D125.

There was a remark that the reduced resolution of the motion data may affect the effectiveness of both this and the reference scheme.

The technique seemed mostly distinct from other proposals affecting the related aspects of the design.

Decision: Adopted Tctr from JCTVC-D164 into the HM.

JCTVC-D431 Crosscheck of Orange's Temporal MV predictor modification Proposal 2.2 JCTVC-D164 [B.Bross (Fraunhofer HHI)] (late registration Friday 21st after start of meeting, uploaded Friday 21st, second day of meeting)

Cross-check for JCTVC-D164. The contributor reported that the code change is small, with no change of syntax or semantics, and indicated that there seems to be no reason why this should not generally provide a benefit, and advocated adoption of the proposal.

JCTVC-D273 Modified derivation process of temporal motion vector predictor [T. Sugio, T. Nishi (Panasonic)]

In this contribution, a modified derivation process of temporal motion vector predictor was proposed. It was proposed that if a motion vector to be referred as co-located partition information is not available, the other motion vector in the partition may be used to derive temporal motion vector predictor, in a manner conceptually the same as in the AVC specification. Experimental results reportedly showed 0.4% BR saving for HE and 0.3% for LC on average in the RA scenarios relative to the TMuC0.9-hm.

This was revisited due to late document JCTVC-D439.

It was remarked that JCTVC-D125 had some similar concepts and supported the basic principles described here (although it reported larger potential gain for a somewhat more complex modification).

Decision: Adopted.

JCTVC-D439 Cross verification of Panasonic proposal JCTVC-D273 [M. Zhou (TI)] (late registration Sunday 23rd after start of meeting, uploaded Sunday 23rd, fourth day of meeting)

Cross-check of JCTVC-D273. The code modification was reported to be straightforward and analogous to AVC processing.

JCTVC-D274 Modified usage of predicted motion vectors in forward directional bi-predictive coding frame [T. Sugio, T. Nishi (Panasonic)]

In this contribution, a modified usage of temporally/spatially predicted motion vector is proposed for B frames that use forward directional bi-prediction. An experimental result reportedly shows 1.0% BR saving for high efficiency and 2.2% BR saving for LC on average in the LD scenario relative to TMuC0.9-hm.

Four aspects were proposed:

- Disable Bi-prediction in Skipped Prediction Units (rather than the current bi-prediction) (about 0.9% in LD LC case)
- Disable Bi-prediction in Direct Prediction Units (rather than sending inter_pred_idc flag) (about 0.3% in LD LC case)
- Modified Reference Index Decision for Skipped and Direct PU, to use the refidx of the majority of neighbors (similar to AVC) (about 0.3% in LD LC case)
- Modified Temporal Motion Vector Predictor (adding an extra temporal candidate to MVP) (about 0.3% in LD LC case)

A combined gain was reported as 1% in LD HE and 2.2% in LD LC usage, with slight reduction in encoding and decoding time.

It was noted that "Direct" prediction is no longer in the design as the result of another decision noted elsewhere in this report.

The proposal was not cross-checked.

Further study was recommended (e.g., in a CE).

JCTVC-D337 Improved motion vector predictor selection in AMVP [I.-K. Kim, T. Lee (Samsung)]

This contribution proposed encoder-only modification of the motion vector predictor selection in AMVP implementation. The proposed method compares RD-cost with all motion vector predictors combination for all reference indices with zero MVD rather than using the template matching. This contribution uses the same interpolation filter and distortion method of motion estimation when setting the initial motion vector predictor to be used as motion search starting point. The experimental result reportedly shows 0.3%, 0.4%, 0.6%, and 0.4% BD BR reductions for high efficiency random access (HE-RA), low complexity random access (LC-RA), high efficiency low delay (HE-LD), and low complexity low delay (LC-LD), respectively.

Decision: Adopted as a switchable encoder-only feature that is disabled by default.

JCTVC-D126 Parsing Error Control for Advanced Motion Vector Prediction [Jian-Liang Lin, Yu-Wen Huang, Chih-Ming Fu, Ching-Yeh Chen, Yu-Pao Tsai, Shawmin Lei]

Advanced motion vector prediction (AMVP) is used in the current high efficiency video coding (HEVC) draft standard. However, the current AMVP design can reportedly have a severe error propagation problem. In this proposal, new syntax elements are proposed for the sequence parameter set (SPS) and the slice header to constrain the use of temporal motion vector prediction (MVP) candidates in AMVP. It was asserted that the parsing error can then be confined to within a few pictures instead of having uncontrolled propagation to many pictures. The proposed syntax design reportedly provides multiple trade-off points between parsing error resilience and coding efficiency.

In discussion, the idea was proposed to constrain the usage of temporal candidates by sending flags at the SPS as follows: First flag: Disabling TP; second flag: Disable temporal candidates for reference frames; Third flag in slice header: Disallowing use for current slice.

It was noted that, in spirit, the first flag is identical to "robust reference 1" of JCTVC-D197.

JCTVC-D197 Proposition for robust parsing with temporal predictor [J. Jung, G. Clare]

As previously noted by Sharp in JCTVC-C257, there is an error resilience issue in the current HEVC design. The problem is related to the parsing of the motion predictor index when previous reference frames are missing. The existing predictor-index signaling method, in combination with the use of a temporal predictor, results in a failure to be able to parse the predictor index unless all reference frames are present.

Four basic solutions for making the parsing robust are studied. All of them bring BR degradation between 1.5 and 2%. Another scheme using a modified temporal predictor is proposed. The average loss compared to these basic solutions is reduced.

- Robust reference 0: Replace unavailable predictors with a default value, such as 0.
- Robust reference 1: "Spatial Only"
- Robust reference 2: "Median Only" – Motion Vector Competition is disabled
- Robust reference 3: "T + Median"
- Robust reference 4: "Full idx" – signal the predictor index in a way that does not depend on the size of the set of predictors.

All methods lead to losses; #4 (sending index) increases the bit rate by 1.2%. The proposed method is to use this method along with modified temporal reference (from JCTVC-D164), which give a BR decrease of 0.1%.

The main problem is usage of the temporal predictor in cases in cases where the previous frame is lost.

JCTVC-D139 Constrained temporal motion vector prediction for error resilience [B. Li (USTC), J. Xu (Microsoft), F. Wu (Microsoft), H. Li (USTC)]

In the current AMVP design, up to 5 MV predictors, including one predictor from a temporal co-located block, are used. The temporal motion vector predictor brings coding gains, but it is reported to be very unfriendly to errors. A small transmission error can reportedly mostly likely lead to a failure of even entropy decoding of all the subsequent dependent inter frames. This document presents testing results of the coding performance brought by temporal motion vector predictors and proposes a scheme to make a tradeoff between coding efficiency and error resilience by disabling the temporal motion vector predictor for some frames.

In the case of loss of the temporal predictor, the entropy decoding process of the current slice is influenced (something that could never happen in AVC where entropy decoding of a slice is completely independent).

- Solution 1: Disable temporal predictor
- Solution 2: Do not use max value in parsing

Another suggested solution: Disable temporal predictor only in some frames

JCTVC-D335 Cross verification on constrained temporal motion vector prediction for error resilience (JCTVC-D139) from Microsoft [I.-K. Kim, T. Lee (Samsung)]

Cross-verification of JCTVC-D139.

It was recommended to establish an AHG that would consider parsing problems in lossy transmission, including the following mandates:

- Study solutions from the input contribs
- Experimentation with effects of single-frame losses as conducted in JCTVC-D139

17.9 Inter Mode Coding

JCTVC-D051 Merge/Skip/Direct Simplification [Y. H. Tan, C. Yeo, Z. Li (I2R)]

In the current HEVC Test Model, there are several ways of coding an inter CU that does not encode motion vector differences. This proposal presents a coding scheme that aims to simplify the Merge/Skip/Direct mechanisms within the current design. Despite being asserted to be a simpler design that results in a 13-27% encoding time decrease, the proposed scheme reportedly demonstrates better coding performance compared to the reference for most test cases.

This proposal relates to CE9, and the preceding discussion of other proposals resulted in preliminary decisions that changed the current target design.

This contribution proposed a simplification that is somewhat different than in other proposals. Further study was encouraged (e.g., in a CE).

JCTVC-D267 Crosscheck of Institute for Infocomm Research's temporal merge proposal (JCTVC-D051) by Qualcomm [R. Joshi, W.-J. Chien]

Cross-check of JCTVC-D051.

JCTVC-D084 On signaling method for prediction modes [Jaehyun Lim, Byoengmoon Jeon]

This document presented a scheme for signaling of prediction modes in inter slices. Different from the specification in the HM, the prediction mode and partitioning type for inter slices were jointly coded with the unary-type codewords in the HM software. The distribution of prediction modes had been investigated and the codeword representing prediction mode and partitioning type was rearranged according to the portion of each prediction mode. The simulation results reportedly showed that the proposed method achieves 0.0% and 0.3% bit rate reductions for HE and LC configurations, respectively, in the CU MRG case, and 0.0% and 0.5% in the PU MRG, case without additional signaling overhead or complexity increase.

The previous discussions, plans had been made to change the related parts of the design.

Further study was encouraged (e.g., in a CE).

JCTVC-D089 Redundancy of Bi-directional Inter Prediction in Generalized P and B picture [Joonyoung Park, Younghee Choi, Byeongmoon Jeon]

This document reportedly describes a redundancy in the design of bi-directional inter prediction in Generalized P/B picture (GPB) and reports a marginal gain when it is removed. Compared to TMuC 0.9 anchors, there are 0.1% BD BR reduction for random-access high-efficiency configuration and 0.1% BD BR reduction for low-delay high-efficiency configuration, on average.

The case described is when there are two ways of indicating the same combination of pictures for bi-prediction.

The proposal is to add some logic to the parsing process so that some pictures are removed from consideration as indexes in reference picture list 1 under certain conditions (when the two lists contain the same pictures). Cases where the reference index in list 1 is greater than the reference index in list 0 were proposed to be removed from consideration.

It was remarked that weighted prediction may be affected by such a change and noted that we have not settled on a plan for weighted prediction in HEVC.

No cross-verification was available.

Further study was recommended (e.g., in a CE).

JCTVC-D140 Adaptive coding order for skip and split flags in LCEC [B. Li (USTC), J. Xu (Microsoft), F. Wu (Microsoft), H. Li (USTC)]

In the current HEVC design, a quad-tree based hierarchical representation is used to handle variable CU sizes. When the current CU size is larger than smallest supported CU size, a flag, called the split flag, is used to indicate whether the current CU is split into smaller CUs or not. For the CU that will not be further split, a flag, called the skip flag, is used to indicate whether the current CU is coded in skip mode or not. This contribution describes an algorithm to adjust the coding order of the two flags mentioned above for LCEC coding. For RA_LC case and LD_LC cases, average 0.4% and 0.6% bit-saving are reportedly achieved with no appreciable impact on complexity at both the encoder and decoder sides. For class E, the average reported BR savings is 2.3%.

The decision about swapping the split and skip signaling is obtained from three surrounding LCUs by counting the number of cases.

JCTVC-D370 (CE5) is related, as well as the open issues in CE9. A breakout group had been tasked with working on the CE9 issues (coordinated by Woo-Jin Han). It was suggested to further consider the proposal in a future CE5 (counter-based adaptation).

JCTVC-D141 Improvement and extension of inter prediction direction and reference frame index combined coding in LCEC [B. Li (USTC), J. Xu (Microsoft), F. Wu (Microsoft), H. Li (USTC)]

In the current TMuC 0.9, inter prediction direction and reference frame index are combined for coding by LCEC. But this combined coding can only be used when the number of reference frames is not larger than 2. This contribution presents a modification of the combined coding and also extends the combined coding to any number of references. For the modification of the current combined coding, average 0.3% bits saving are reported for the RA_LC and LD_LC cases. When using 3 references, extending the combined coding to an arbitrary number of reference frames reportedly leads to average 0.5% and 0.4% BR savings for RA_LC and LD_LC cases. The proposed algorithm reportedly does not impact the complexity at either the encoder or decoder side.

- First element: When there is up to one frame in each list, the value 1 is never used, so it is moved to back of lookup table (same to JCTVC-D184)
- Second element: Direct mode: If only one list is used within a CU, it is not necessary to code the directions (was also implemented by proponents of JCTVC-D184 and confirmed)
- Third element: Restrict value of max number of probabilities (same to JCTVC-D184)
- Fourth element: "bug fix ticket 108" (encodes information twice) – Decision: Agreed
- Fifth element: Lookup table extended from 8 entries to 9 entries, where the first eight entries have the same meaning as with the current coding scheme, and the ninth entry means at least one reference frame index is greater than or equal to 2

An expert suggested that this provides a solution to something that was left open when implementing LCEC into the initial TMuC (efficient signaling of more than 2 ref frames, and the case when list1 does not exist)

JCTVC-D310 Cross-check results of MSRA's proposals JCTVC-D138, JCTVC-D140, JCTVC-D141 and JCTVC-D142 by Huawei [J. Zhou, H. Yang]

Cross-check for JCTVC-D138, JCTVC-D140, JCTVC-D141 and JCTVC-D142.

JCTVC-D184 Reduced redundancy of the low complexity entropy coder (LCEC) [Hisao Sasai, Takahiro Nishi]

In the current HEVC specification, a joint adaptive VLC coding is used for reference frame index and inter prediction direction in the low complexity entropy coder (LCEC). As the total number of reference frame index is known at the picture level, there is redundancy in using an unlimited VLC table length for the coding of the reference frame index. This contribution reports an experimental result in which the number of VLC table indexes is determined by the total number of reference frame indexes and used at the PU level. Compared to TMuC0.9-hm anchors, such a change reportedly leads to 0.3% BR saving for the random-access case and 0.0% BR saving for low-delay cases without any significant complexity increase, on average.

Decision: Adopt solution from JCTVC-D141/JCTVC-D184 (JCTVC-D141 is superset) – partially w.r.t. sub-item (2) depending on the status of DM.

JCTVC-D254 Enhanced Context Modeling for Skip and Split Flag [Xiaoyin Che, Wenpeng Ding, Yunhui Shi, Baocai Yin (Beijing Univ. Tech.)] (missing prior, uploaded Tuesday 18th, before meeting)

CABAC is used in the HM HE configurations. The coding efficiency depends on the context-based probability distribution of symbols. This contribution proposes a new context model for entropy coding of the SplitFlag for CU subdivision and the SkipFlag for CU skipping, by using both the depth and neighboring flags as context.

It was proposed to use more contexts for these two flags.

No substantial coding efficiency improvement was reported at this time.

Further study was encouraged in this area.

JCTVC-D275 Adaptive Coding of PredMode Syntax Elements [Wen Zhang, Dong Wang, Yingjie Hong, Wen Zuo, Ming Li (ZTE Corp)]

In the current TMuC0.9-hm, each CU employs some syntax elements of PredMode to signal its inter-frame prediction mode, where a fixed coding order and mapping method are used to code PredMode information. However, the statistical characteristics of different elements for PredMode vary among slices, which will leave some redundancy in coding PredMode information, especially when SKIP_MODE is not the highest probable case in the current coding slice. From the perspective of the efficiency issue of variable length coding, the event of the highest probability should be assigned with the shortest codeword. It was asserted that the coding efficiency of the PredMode information can be further improved by adaptively adjusting the coding order for the related elements at the slice level. A new syntax element pred_mode_coding_type was proposed to be added in the slice header to specify the coding type of the PredMode related elements in current slice. The encoder determines the value of pred_mode_coding_type based on the estimated statistical features of the previous coded slices, which results in adaptive coding of the PredMode syntax elements at slice or frame level.

Average bit rate savings of 1.2% and 0.6% were reported for LC RA and LC LD, respectively.

Basically no gain was reported for the HE cases.

No cross-verification was available.

It was remarked that JCTVC-D370 may affect this topic (although it may not address the slice adaptive aspect, so this contribution may lead to further gain after additional study of the topic is conducted).

Further study was encouraged.

JCTVC-D401 Comments on Generalized P/B Pictures [Y. Chen, M. Coban, W.-J. Chien, M. Karczewicz (Qualcomm)]

Generalized P/B (GPB) pictures are supported in the working draft of HEVC. Comments on the GPB pictures were given in this proposal, on the related modifications for slice level syntax elements and decoding processes for such a picture.

The asserted issues of the current GPB design are as follows.

- No explicit way to indicate whether a B slice is a GPB slice or a "normal" B slice. It is necessary for the decoder to identify whether a slice is a GPB slice since the parsing of the syntax element (inter_pred_idc) in prediction units relies on it. So, for each slice, a comparison of the reference picture list 0 and reference picture list 1 must be done to determine whether a slice is a GPB slice.
- Given the information of reference picture list 0, the signaling of the information of reference picture list 1 for a GPB slice is redundant, since the reference picture list 1 and the reference picture list 0 are identical in such cases. However, such a redundant signaling is not prohibited in the current design. The redundantly signaled syntax elements include

num_ref_idx_l1_active_minus1 and the reference picture list modification (RPLM) table. They both use a certain amount of bits which are asserted to be useless.

- For a GPB slice, the decoding processes for reference picture list construction of the list 1 are reportedly useless.

It was proposed to either send a flag to identify whether a B slice has two lists or just one, or to create a new slice type value.

No experiment results (or cross-verification) were provided, as the concept was considered to be easily understood without such results.

It was discussed how to identify exactly what a "GPB slice" is, and it was suggested that a current definition would be that it is a B slice in which the two reference picture lists are identical (which currently results in excluding single-list prediction using list 1 reference pictures).

There was some hesitation expressed about introducing such a change at this time – it seems like something like this may be desirable at some future time if the design remains stable, but may not be worth tinkering with at this stage. It was suggested that we should just keep in mind this idea for potential future adoption if the proposal is still relevant after a few more meeting cycles.

JCTVC-D421 Extension of uni-prediction simplification in B slices [Y. Suzuki, TK Tan (NTT DOCOMO), W. J. Chien, Y. Chen, P. Chen, M. Coban (Qualcomm)] (late registration Thursday 20th after start of meeting, uploaded Thursday 20th, first day of meeting)

In this contribution a simplification for the entropy coding of the prediction mode in the "generalized" B slices was proposed to be further extended to cover more cases than just in the situation where list 0 and list 1 are identical. It was reported that the same benefit can be achieved for other cases where list 0 and list 1 share common entries but are not identical.

The proposal is to first create the two lists in the ordinary fashion, then to create a combined list by interleaving the pictures from the two individual lists (starting with list 0) while removing any duplicates. For bi-prediction, the two individual lists are used and for single list prediction, the combined list is used.

This is proposed to be applied to all B pictures, including those currently called "GPB". MV storage identifies a motion vector as being associated with the list it originally came from when creating the combined list.

It was remarked that, hypothetically, modification of the combined list after its initial creation could be supported (as well as modification of the initial lists prior to the creation of the combined list).

When used with the JCTVC-C500 common conditions, the scheme reportedly has approximately no impact on coding efficiency. With two reference pictures in each list (like our newly-adopted common conditions), an improvement of 0.3% and 0.5% was reported for HE RA and LC RA, respectively. For LD, approximately no impact would be expected (since the combined list would be identical to each of the original two lists).

In the case where more pictures are placed into L0 (4 pictures) than in L1 (2 pictures), the additional gain reported for the technique was 0.6% and 0.8% for HE RA and LC RA, respectively.

In a similar use case for LD, the additional gain reported for the technique was 0.6% and 1.0% for HE LD and LC LD, respectively. (Note that in this case, the current HM uses two lists for single-list prediction because one list is a subset of the other rather than being identical.)

The reported encoding times are reduced (6-30%), due to the elimination of some search candidates for single-list prediction. This complexity reduction could have been achieved without changing the decoding process, but no gain would be likely to be exhibited in such a case.

It was remarked that, without constructing the two lists, the length of the combined list will be unknown, and the bitstream cannot be parsed. The proponent responded that the length of the combined list could be sent in syntax to avoid this issue.

It was again remarked, as in the discussion of another proposal, that weighted prediction would be affected by this proposal. The proponent remarked that it should be trivial to deal with that issue.

No cross-verification was available yet when this was initially discussed, although there was reported to be some cross-verification work under way.

The list of authors on the contribution was changed in Version 3 of 2011-01-25 to add W. J. Chien, Y. Chen, P. Chen, M. Coban (Qualcomm).

Version 3 (r1 of the Word document) includes a new syntax element ref_pic_list_modification_flag_lc (which was asserted to make it more consistent with the existing design) and adds semantics for ref_pic_list_combination_flag.

JCTVC-D442 Cross-verification results for JCTVC-D421 [B. Li (USTC), J. Xu (Microsoft)] (late registration Monday 24th after start of meeting, uploaded Monday 24th, fifth day of meeting)

Presented in Track B Wednesday afternoon.

Decision: Adopt JCTVC-D421

Remark by chair (regarding JCTVC-D421): Adoption of this is an exceptional case and should not encourage late contributions submissions in the future.

17.10 High-Level Syntax

JCTVC-D080 On NAL unit header [Y.-K. Wang, Z. Wu (Huawei)]

This document discusses the HEVC NAL unit header syntax and proposes the following:

- To reduce nal_ref_idc to a single bit
- To include temporal_id in SEI NAL unit headers
- To include indication of anchor picture (i.e. open-GOP picture) in NAL unit header
- To discuss indication of intra picture in NAL unit header

It was remarked that the semantics of nal_ref_idc should be clarified in the WD.

It was noted the nal_ref_idc has a meaning in the AVC RTP payload specification, but the proponent indicated that this feature was not really being used by implementation (to the best of his awareness).

Somewhat mixed feelings were expressed in the group discussion about the proposed change of nal_ref_idc.

Regarding inclusion of a temporal ID in SEI NAL unit headers. The proponent noted that temporal ID is already included in VCL NAL unit headers.

A participant asked how to indicate an SEI message that applies to all temporal layers.

What this refers to as an "anchor picture" is equivalent to a picture with a recovery_frame_cnt equal to 0.

The proponent suggested to use a flag for this purpose.

A participant remarked that perhaps rather than adding a flag or using an additional nal unit type (NUT) value, we could replace the existing meaning of NUT=5 to become an indication of an anchor picture rather than an indication of an IDR picture – perhaps putting a flag in the slice header to indicate whether the anchor picture is an IDR picture. Another participant said that it may be preferable to be able to make the distinction at the NAL unit header level, using a different NUT value.

It was remarked that JCTVC-D234 has some potential relationship to this.

Regarding the last item in the proposal, there was a similar reaction.

It was remarked that the access unit delimiter (AUD) could be another place to put such information, and that we might want to consider making AUDs mandatory.

Decision: Adopted an addition NUT value that indicates a non-IDR "anchor" (clean random access intra) picture. The other aspects should be studied further.

JCTVC-D081 On reference picture list construction [Y.-K. Wang, Z. Wu (Huawei)]

This document proposed to change the reference picture list construction process such that any reference picture with a greater temporal_id value would never appear in the reference picture list of a slice during its reference picture list construction process.

It was remarked that this same change was proposed in JCTVC-D200.

Decision: Adopted this aspect.

The contribution further discusses the need (or lack thereof) of gaps_in_frame_num_value_allowed_flag in the sequence parameter set and the related processes for generating and handling "non-existing" pictures needed when there is a gap between frame_num values. In discussions, it was remarked that this flag seems to provide a valuable indicator of whether a missing frame_num value should be interpreted as a problem or not, so it (or something like it) should be retained. Further study was recommended in regard to whether the gap filling specification of inserting "non-existing" pictures into the reference picture list is still useful to retain.

The WD should be studied carefully to consider its handling of related aspects, and identify necessary corrective action.

JCTVC-D082 On SEI messages [Y.-K. Wang, Z. Wu (Huawei)]

This document discussed the topic of reusing the SEI messages defined in AVC (as well as in SVC and MVC) in HEVC. A table was provided with a comment for each SEI message, which included opinions on whether an SEI message should be supported (if not, the reason), revised, or changed, and so on.

It is proposed to study the applicability of the AVC (including its SVC and MVC extensions) SEI messages in HEVC, and reuse those that are applicable. It is further proposed to use the table in this document as the starting point for the study.

The reuse of AVC high-level syntax had been documented in JCTVC-B121, as a starting point. Consensus was also reached to keep the SEI message mechanism, but the details related to which HEVC SEI messages can be inherited from AVC had reportedly not been mentioned. Thus, it was proposed to study the applicability of the AVC (including the SVC and MVC extensions) SEI messages to HEVC, and reuse those that are applicable. This document presented such an initial study. It was further proposed to use the table provided in this document as the starting point for further related study.

In discussions of the proposal, it was agreed that filler_payload, user_data_registered_itu_t_t35, and user_data_unregistered are commonly used and should be retained. It was also agreed that there may be some useful aspects to sub_seq_info. It was additionally agreed that full_frame_snapshot, progressive_refinement_segment_start, and progressive_refinement_segment_end also seem useful and should probably be retained.

Decision: As revised above, this was agreed as our starting point.

JCTVC-D200 High layer syntax to improve support for temporal scalability [J. Boyce, D. Hong, A. Eleftheriadis (Vidyo)]

High layer syntax changes were proposed to improve support for temporal scalability in the HEVC design. The contribution proposes adding normative semantics for temporal_id, adding a temporal_switching_point_flag to the NAL unit header, moving temporal_id_nesting_flag to the sequence parameter set, and an SEI message to describe the temporal coding picture structure for the sequence. The proposed changes were asserted to bring benefits to bitstream extractors, transraters, and parallel decoding.

There were three elements in this proposal:

- Omitting higher temporal layers when forming reference picture lists
- Indicators for temporal level switching
- An indicator for describing a pattern of picture referencing used in a series of pictures

The omission of pictures from higher temporal layers when forming reference picture lists, as also advocated in JCTVC-D081.

The contribution requested an indication of when it is possible to switch up a level in the nesting structure. It was proposed to provide a sequence-level indicator that, when set to 1, would indicate that it is always possible to switch up from any layer, and additionally to send a NAL unit level flag to provide such an indication on each individual picture (where the NAL unit level flag is always set to 1 when the sequence-level flag is set to 1). The indicator would be used to mark preceding pictures of the same temporal level and higher temporal levels as not used for reference.

It was remarked that some cases that are described by the temporal level switching point SEI message cannot be handled by this.

Further study was recommended for this aspect, as we have not seen it before and there may be other aspects of high-level syntax

In parallel discussions, it was recommended to establish an AHG on HL syntax and SEI messages.

A third aspect was a proposal of an SEI message to describe a coded picture pattern used in each series of pictures within a coded video sequence.

A participant remarked that it may be useful to send an indicator, on a picture basis, of the current position in the pattern.

A participant remarked that it may be useful to have a way to interrupt the described pattern (e.g., due to a scene change detection).

The group was favorably disposed to the proposal, but desired further study in AHG work rather than immediate adoption.

JCTVC-D127 Leaf Coding Unit Aligned Slices [Chih-Wei Hsu, Chia-Yang Tsai, Yu-Wen Huang, Ching-Yeh Chen, Chih-Ming Fu, Shawmin Lei]

In the current high efficiency video coding (HEVC) working draft (WD), one picture can be partitioned into multiple largest coding unit (LCU) aligned slices, and each slice contains an integer number of LCUs. However, only one slice per picture can be supported in the current HEVC test model (HM). Moreover, the LCU size can be 64x64, which is 16 times the size of a macroblock in prior video coding standards. It was asserted that using 64x64 LCUs as basic units of a slice may not be able to provide enough flexibility for rate control. Hence, leaf coding unit (CU) aligned slices are proposed in this contribution wherein each slice can contain a fractional number of LCUs, and slice boundaries are aligned with leaf CU boundaries instead of LCU boundaries. A new syntax design and a software based on test model under consideration version 0.9 (TMuC0.9) that can support both LCU aligned and leaf CU aligned slices were developed. For low complexity entropy coding (LCEC), it was reported that termination of a slice can be indicated by an rbsp_stop_one_bit, so supporting leaf CU aligned slices can be straightforward with minor changes. For context-based adaptive binary arithmetic coding (CABAC), the end_of_slice_flag is used to indicate if a slice is terminated. Instead of sending one end_of_slice_flag for each leaf CU, a hierarchical method is designed to reduce the number of flags. At the beginning of each LCU, a last_lcu_possible_flag is transmitted to indicate if the current LCU is possibly the last LCU of the current slice. Only when the last_lcu_possible_flag is equal to 1, an end_of_slice_flag is coded for each leaf CU of the current LCU. Simulation results reportedly show that the proposed syntax design and software can support both LCU aligned and leaf CU aligned slices without any mismatch between encoder and decoder sides. For the case of a fixed number of LCUs per slice, the coding efficiency of the LCU aligned slices of our software is similar to that of the slice ad-hoc group (AHG) software, which only can support LCU aligned slices. For the case of fixed number of bytes per slice, it was reported that leaf CU aligned slices can easily fit target bit rates much better than LCU aligned slices. When 1500 bytes per slice is considered, the BR inaccuracies of LCU aligned slices are reportedly 5%-14%, and BR inaccuracies of leaf CU aligned slices are reportedly only 1%-3%.

The proponent does not suggest to replace the current syntax with the proposed syntax, but rather to add an additional type of slice operation in addition to LCU aligned slice operation.

A participant remarked that it may be difficult to determine how to set the proposed last_lcu_possible_flag prior to encoding an LCU (without excessive overhead for repeated use of the proposed end_of_slice_flag).

Some interaction issues with ALF were discussed.

It was noted that MTU size limits can be achieved by packet fragmentation or similar techniques, although it was remarked that this causes significant problem in some applications.

Some identified issues include:

- How to minimize the quantity of overhead data (and compare this to suboptimalities produced by alternative approaches).
- The complication of the decoding process due to having unusual starting and ending positions within an LCU.
- The causality issue of needing to identify, prior to the start of encoding an LCU, whether the slice may end within that LCU (and perhaps to attempt to "rewind" and change a decision).

It was remarked that JCTVC-D383 is related, and concerns how exactly to detect the end of a slice when CABAC is in use. It was asserted in that contribution that no overhead is needed until the stop is indicated at a position, if the rbsp_stop_bit is used to identify the end of the payload segment.

Further study was suggested (e.g., in a CE).

JCTVC-D387 Cross-verification of JCTVC-D127: Leaf Coding Unit Aligned Slices [R. Sjöberg, P. Wennersten (Ericsson)]

Cross-verification of JCTVC-D127.

JCTVC-D312 Fine granularity slice partition [Q. Shen, Q. Xie, H. Yu]

This proposal was similar in spirit to JCTVC-D127.

Further study was encouraged (perhaps in a slice AHG).

JCTVC-D128 Slice Boundary Processing and Picture Layer RBSP [Chia-Yang Tsai, Chih-Wei Hsu, Yu-Wen Huang, Ching-Yeh Chen, Chih-Ming Fu, Shawmin Lei (MediaTek)]

In this proposal, three issues related to slices are presented.

- Adding support for slice-independent deblocking filter (DF) and slice-independent adaptive loop filter (ALF) were proposed. In slice-independent DF and ALF, DF is not performed across slice boundaries, and a padding method is used for ALF to replace any originally required pixels out of the current slice. With the modified DF and ALF processes, each slice can be independently decoded without using any data from other slices. It was remarked that this is a feature supported in AVC, but it was apparently not considered when studying which features to carry forward into HEVC.

Decision: Adopted (a single indicator in the slice header that disables both DF and ALF across slice boundaries).

- A slice boundary filter (SBF), which is proposed to be similar to DF but only processes slice boundaries, is proposed to remove possible artifacts across slice boundaries that may be caused by slice-independent DF and ALF. It was noted by the contributor that this could either be done within the prediction loop or outside of it. The proposed SBF is essentially the same as the DF except for the order of the processing. It was remarked that other ways of dealing with the sequential dependencies of the DF have already been discussed and will be further discussed, which may make this proposal unnecessary (by making the result be the same even when the processing order is different). Contribution JCTVC-D263 seems to be related to this aspect.
- Third, a picture layer raw byte sequence payload (RBSP) is proposed as an option for sharing common information among slice headers in a picture. Syntax elements that can be moved from the slice header to the picture layer RBSP when they are the same for all slices include slice type, slice quantization parameter, entropy coding mode, interpolation filter type, number of reference pictures, ALF coefficients, …etc. Simulation results reportedly show that the provided software, as proofs of the concepts, can successfully support all the new features without any mismatch between the encoder and the decoder.

In some experiments using 4 slices per picture, the proponent report a BR savings of roughly 0.4% for moving some syntax from the slice level to the proposed picture level.

It was remarked that the current syntax already has a picture level, known as the picture parameter set (PPS).

We can consider (e.g., optionally) moving more syntax elements into the PPS, including, for example, the picture order count information. This can be discussed in the AHG on high-level syntax.

JCTVC-D227 Replacing slices with tiles for high level parallelism [A. Fuldseth (Cisco)]

This contribution proposes introducing "tiles" as an alternative to slices for better support for high level parallelism in HEVC. While slices follows the raster scan order of LCUs, tiles have a fixed rectangular shape that is signaled in the sequence parameter set or in the picture parameter set. Furthermore, tiles reportedly come without the overhead associated with slice headers, and it is argued that it allows for better load balancing, lower delay, and more fine-grained parallelism than slices. Finally, tiles can co-exist with slices, are optional in the encoder and were asserted to have a negligible impact on the decoder design. Experimental results using the low complexity low delay configuration with one tile/slice per LCU row, reportedly showed that the BD BR gain when using tiles instead of slices is significant.

The concept is to be friendly to parallel encoders (not parallel decoders).

The proposal does not change the order in which LCUs are sent to the decoder, but resets (and perhaps flushes, in the CABAC case, and perhaps pads for byte alignement) the entropy coder at each column boundary location within a tile.

Intra prediction is reset at tile boundaries in a similar manner as for slice boundaries.

The overhead bits otherwise used for slice headers are avoided. The segments of the bitstream are re-ordered in the encoder to produce a raster-scan-order output bitstream.

With this scheme, it is possible to perform "stitching" in the compressed domain if the encoder restricts its motion vector selection in a particular way.

The reported experiment results did not address the column split aspect of the proposal – only full-row tiles/slices with one tile/slice per row were studied in this experiment, with the benefit that is measured being basically the elimination of slice headers.

The basic concept is that if the purpose of using the segmentation of the picture is for encoder parallelism rather than loss robustness or packetization or some other purpose, then there may be no need to send slice headers.

In contrast to "entropy slices", this proposal resets more decoder state at boundaries – not just the entropy coder, but also, for example, intra prediction and motion vector prediction. These "tiles" are basically slices (or rectangular slice groups) without headers (sort of).

It was remarked that this could be combined in some way with the entropy slice concept.

It was remarked that perhaps there is no need to rearrange the coding order to produce raster scan order.

It was remarked that having the tiles all the same size (or mostly the same size, except perhaps at the edges of the picture) may be beneficial.

It was remarked that JCTVC-D052 through JCTVC-D054 are related.

Further study was encouraged (perhaps in a slice AHG).

JCTVC-D378 Generalized slices [M. Horowitz, S. Xu (eBrisk Video)]

This contribution presents a proposed scheme that the proponent calls generalized slices (GS). This is a video coding construct that provides more options for partitioning a video picture compared to standards with less flexible picture partitioning (e.g., H.264/AVC with the number of slice groups equal to 1). Specifically, GS introduces vertical slice boundaries that partition a picture into columns in a manner reminiscent of Rectangular Slices (H.263 Annex K). Introduction of vertical slice boundaries enables an encoder to encode slices that have a lower normalized moment of inertia (i.e., they have a more square shape) which typically results in greater homogeneity of content within a slice and increases the ratio of slice area to slice boundary – reportedly leading to improved coding efficiency. Coding units are processed in raster scan order within each column. Results are presented reportedly demonstrating that GS provides an average 2.0%, 1.3%, and 1.6% Y BD BR advantage for Random Access, Low Delay, and Intra cases respectively, compared with an identically configured encoder using the same number of scan-order slices.

Further study was encouraged (perhaps in a slice AHG).

JCTVC-D070 Lightweight slicing for entropy coding [Kiran Misra, Andrew Segall]

This contribution proposed a method for slicing of entropy coded data that is often referred to as "entropy slices." The goal of entropy slices was asserted to be to provide a simple and direct extension of the HM design to evolving CPU/GPU architectures. In this scenario, the entropy decoding and reconstruction operations are typically assigned to the CPU and GPU, respectively, and the contribution advocated flexibility in the slicing to address this anticipated use case. Specifically, the contributor advocated dividing a traditional slice into additional entropy slices that are can be parsed without reference to other entropy slices. This enables the use of multi-core CPUs to handle the entropy decoding process in an efficient manner. While the entropy slice system is initially motivated by this use case, it was reported that it is also useful for other scenarios – including homogeneous decoder architectures. This contribution described the design of the entropy slice system and reported current results.

Experiment results were reported with a limit of 180 000 bins per slice, with a decrease of 0.1-0.2% in coding efficiency (where the value of 180 000 was selected such that the maximum number of slices that were produced in any picture in the text set for this limit was 32).

It was remarked that the need to buffer the decoded syntax elements after parsing in order to take advantage of the parallelism at the decoder side is such a burden that it may not be desirable to implement the envisioned parallel parsing process. The proponent, cited as an example, a hybrid CPU/GPU decoding process with parsing on the CPU and an intermediate data representation sent to the GPU processing elements that perform the remainder of the decoding process.

A few participants indicated that they thought the scenario in which this would provide a benefit was too narrow to justify the associated envisioned bitstream constraint and requirement for decoders to be capable of handling a different type of slice in addition to an ordinary slice.

It was pointed out that the support for the feature could be profile-dependent.

It was remarked that motion vector prediction might be difficult to harmonize with this; however, the proponent indicated that the feature has been integrated into the HM without difficulty, with motion vectors outside of the entropy slice treated as not available.

It was remarked that JCTVC-D243 and JCTVC-D430 are closely related.

Decision: Adopted (disabled in the common conditions, which don't use slices anyway).

JCTVC-D209 Cross-check report on Sharp entropy slices (JCTVC-D070) [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda (NEC)]

Cross-check of JCTVC-D070. The cross-checker reported that the runtime increase for the decoder was very small, and indicated that they carefully studied and checked the software, and also that they found it simple to integrate into the software – suggesting it to be a straightforward approach that is similar in its handling to the use of ordinary slice structured coding. It was also reported that the software matched the proposal description.

JCTVC-D396 On Slice Granularity [Y. Chen, P. Chen, M. Karczewicz]

Some experiments were reported to study the quantity of data produced by each LCU in a few test video clips with QP = 22. It was reported that with LCU size of 64x64 and all-intra coding, most individual LCUs produced a large fraction of the typical reference MTU size of 1500 bytes for some test sequences.

The contributor therefore advocated for slice granularity to be supported at a finer degree of granularity than at LCU boundaries. The proponent advocated to be able to indicate the degree of such granularity at the picture parameter set level.

The contribution did not advocate a specific syntax for slice structure representation, so the proposal is more a concept-level motivation proposal than a specific design ready for action.

It was noted that an alternative way to achieve a finer granularity is to use a smaller LCU size. The contribution did not report on the coding efficiency benefit of using the 64x64 size rather than a smaller size. It was conjectured that since this was all-intra coding, there may be very little such benefit.

It was remarked that the desirability of supporting the finer granularity without using a smaller LCU size would depend on the particular characteristics of a proposed detailed design for achieving such granularity – e.g., in terms of the complexity of making effective use of the feature for encoding and decoding.

JCTVC-D430 Evaluation of Entropy Slices [M. Coban, M. Karczewicz] (late registration Friday 21st after start of meeting, uploaded Friday 21st, second day of meeting)

The proponent indicated that it was not necessary to give detailed presentation of this contribution; participants are invited to study the contribution document.

17.11 Quantization

JCTVC-D024 Compact representation of quantization matrices for HEVC [M. Zhou, V. Sze (TI)]

Due to large block size transform and quantization used in the HEVC, carrying the quantization matrices in the picture parameter set will lead to a significant overhead. In this document, a quantization matrix compression algorithm is proposed to achieve compact representation of quantization matrices for HEVC. The algorithm reportedly provides 7x more compression when compared to the AVC quantization matrix compression method if all the compression steps are enabled. It was recommended to set up an ad-hoc group to investigate the perceptual quantization of the HEVC coding with large block transforms, and to specify the compact quantization matrix representation format for efficient carriage of the quantization matrices in the HEVC picture parameter set.

Compression of the quantization matrix is lossy

The effect on visual quality was not investigated.

It was asked whether the compression technique guarantees some maximum error for the individual elements of the matrix.

It was suggested that, potentially, definition of a small set of switchable matrices would be better (VQ style).

Would it be appropriate to change quantization matrices for every picture? If not, the compression of the matrices may not be as necessary, particularly as the effect of lossy compression is currently unknown.

This would be a tough subject to study, including subjective investigation – and it was thought doubtful whether we should put much resources into this currently.

JCTVC-D038 Delta QP signaling at sub-LCU level [M. Budagavi, M. Zhou (TI)]

Delta QP is widely used in practice for perceptual quantization and rate control purposes. In the current design of HM 1.0, delta QP is sent only at LCU level i.e. once every 64x64 block. Hence the spatial granularity at which QP can change is reduced when compared to AVC, which allows for signaling of delta QP at the macroblock (16x16) level. The reduced granularity at which delta QP can be signaled in HM 1.0 impacts the visual quality performance of perceptual rate control techniques that adapt the QP based on the source content. This contribution proposes that delta QP be signaled at a sub-LCU level to maintain the spatial granularity of signaling at the level supported by AVC (i.e. at 16x16 blocks). This contribution also presents syntax modifications for sub-LCU level signaling. It also proposes prediction methods for calculating delta QP at sub-LCU levels.

Examples were shown from AVC streams. (In fact many streams also exist that do not change QP at the macroblock level.) A purpose for such a scheme could be rate control or subjective adapted quantization (e.g. lower QP in flat MBs).

For rate control, changes at the CU level would appear to be sufficient.

For subjective adaptation, it is claimed that the ability to change at the level of 16x16 is needed.

Specific scan structures are proposed as the 16x16 blocks are not row-sequential as in AVC.

- It may be difficult to get evidence of at which level the ability to change QP is really needed (unless doing extensive testing)
- It was questioned whether 16x16 QP change ability really needed or if it was only historically at that granularity because the MB size was previously 16x16 all the time
- One independent expert expressed that 64x64 may be a bit too coarse
- There were some other voices raised in favor
- If yes, it would certainly be useful to make it switchable
- A problem how to evaluate the encoding

One idea considered was whether the change of QPs as currently used in AVC streams could be modeled e.g. as a Markov process. It was suggested to study how frequently it changes and by how much.

Further study in some AHG was encouraged – which should include study of the need of more frequent QP changes also in the context of rate control needs.

JCTVC-D041 Finer scaling of quantization parameter [D. Hoang (Zenverge)]

The current Test Model under Consideration (TMuC) employs a quantization parameter (QP) scaling that is borrowed/inherited from the AVC standard design. In AVC, the quantization step size increases by approximately 12.25% with each increment of QP, so that the quantization step size doubles when QP is incremented by 6. For the purpose of rate control, this 12.25% increment was asserted to be too coarse for certain applications, such as low-delay coding. This contribution proposes a specification that allows the granularity of the quantization parameter (QP) to be varied at the slice and picture levels. Backward-compatibility with the AVC approach is maintained at one of the granularity settings. In addition to varying the granularity, this contribution also proposes a variable QP offset that can be specified at the slice and picture levels.

A suggested problem was that, for rate control, the granularity may be too coarse due to the larger CUs (see notes in the context of slice discussions).

It was remarked that delta QP at the sub-CU level could also resolve this issue.

JCTVC-D258 CU Adaptive dQP Syntax Change for Better Decoder pipelining [L. Dong, W. Liu, K. Sato]

The current HM adaptive quantization syntax places "dQP" at the very end of each LCU when the whole LCU is not coded with SKIP mode. Such syntax could introduce delay in decoding. The proposed change is to place "dQP" after the mode information of the 1st non-skipped CU in an LCU. It was asserted that the proposed change will avoid unnecessary decoder delay and avoid unnecessary signaling when an LCU is further partitioned but every sub-CU is then skipped.

It was agreed that this seems to be a reasonable suggestion, but before adopting it should be cross-checked with the originators of the HM software.

Another suggestion was made that it would be better to send this after CBF. This was agreed.

Decision: Adopted (to signal after CBF).

JCTVC-D308 On LBS and Quantization [Kazushi Sato] (initial version rejected as a placeholder upload)

The concept of the Coding Unit has been introduced to HEVC, and it reportedly greatly contributes to coding efficiency improvement. The current HEVC specification defines delta-QP only at the slice level, and in the current HM it can be specified only at the LCU level, but it was asserted that this is not sufficient for subjective quality improvement with the degree of flexibility of QP control as found in MPEG-2/H.262 or AVC, where the size of macroblock is fixed as 16x16.

In this document it is reported that the current dQP specification is not sufficient, and dQP overhead bit usage does not have an impact in coding efficiency if all dQP=0.

The contribution reported results with AQ on/off for LCU sizes 16 and 64. In general, adaptive quantization leads to losses in PSNR.

Overhead of dQP is reportedly 0.47% with QP37 for 16x16 and 0.047% for 64x64. Less overhead (in percentage terms) is used when QP is smaller, since using a small QP implies using more bits for quantized coefficient data.

It was remarked that there is a inconsistency of dQP definition between the current WD and software.

Comments:

- To really show evidence, it would be necessary to implement dQP at the sub-CU level (i.e. use LCU 64x64 with dQP 16x16). For the examples given, adaptive quantization at 64x64 looks better than adaptive quantization at 16x16, which is certainly due to the better compression performance of the 64x64 LCU.
- Is 16x16 dQP really needed for ultra HD? (It was already used for QCIF & CIF traditionally.)

Further study appears needed to get evidence about the necessity of smaller-blocksize QP adaptation. Such further study was encouraged to take place in an associated AHG.

JCTVC-D384 Quantization with Hard-decision Partition and Adaptive Reconstruction Levels for low delay setting [Xiang Yu, Jing Wang, Da-ke He, En-hui Yang (RIM)]

This contribution proposed a quantization scheme for the low-delay low-complexity setting based on "hard decision quantization" and adaptive reconstruction levels. Specifically, for each inter frame, the proposed forward quantization process uses the hard decision quantization as implemented in the HM scheme, following by a statistics collection for reconstruction levels. The reconstruction levels are then selectively transmitted to the decoder and are used for reconstructing the next frame. Compared with the anchor with the low-delay low-complexity setting, the proposed scheme reportedly reduces the computational complexity while boosting the rate distortion coding performance. In terms of RD performance, the proposed scheme reportedly outperforms the reference configuration with the low-delay low-complexity setting by 1.2%, 2.2% and 3.0% by BD BR for the Y, U, and V, respectively; in terms of complexity, the proposed method reportedly saves the RDOQ computation on the encoder side without changing the decoding complexity.

In the proposed method, a delta-i (deviation for quantization cell i) is transmitted when it gives benefit (improvement larger than a threshold).

Runtime reduction (due to RDOQ off) was reported as 6% at encoder, with a slight increase at the decoder.

Partitioning is not changed at the encoder.

Questions/comments

- Reconstruction levels become non-uniformly distributed
- How is it performing in intra-only & random access LC, and in HE cases?
- The differential transmission of delta-i values could be problematic in case of losses – also we should study the case where the actual deviation from a uniform reconstruction quantizer is signaled for each frame.
- When QP is changed, the partitioning is changed. How is that handled? The proponent indicated that a normalization was performed.

Further study appeared needed.

One expert mentioned that using RDOQ in general may not be a widely-supported feature for encoders, so looking into tools that avoid this are interesting.

It was also suggested to put this topic under the mandates of a quantization AHG.

17.12 Entropy Coding

JCTVC-D044 Pulse code modulation mode for HEVC [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda]

This contribution presents the preliminary results of Pulse Code Modulation (PCM) mode encoding in HEVC, for which a single-bit syntax flag is introduced in the PU header in order to signal the use of PCM coding in an associated Intra CU. Experimental results for common test sequences show average BD BR losses of 0.01% (Y), 0.02% (U), 0.02% (V) for all intra high efficiency setting, 1.43% (Y), 1.18% (U), 1.16% (V) for all intra low complexity setting, 0.01% (Y), 0.01% (U), 0.11% (V) for random access high efficiency setting, 0.43% (Y), 0.53% (U), 0.51% (V) for random access low complexity setting, 0.01% (Y), -0.29% (U), -0.02% (V) for low delay high efficiency setting, and 0.15% (Y), 0.19% (U), 0.24% (V) for low delay low complexity setting. Additional experimental results for a synthesized sequence reportedly demonstrate that the use of PCM mode avoids producing a number of bits which is prohibitively greater than that of the input video data and reduces decode time significantly. It is proposed that the concept of PCM mode coding be adopted in HM ver. 2 and that its design be further studied.

Modification compared to AVC I_PCM mode necessary due to IBDI

White Gaussian noise is used as test sequence (as otherwise the PCM mode would not be selected).

Comment: Another issue to be studied is the implication of larger block sizes in HEVC.

It is mentioned that content like (noise) this could locally appear in typical HEVC applications, and this prevents an encoder from weird decisions.

Further study appeared needed – establishing some AHG that would study this was advised.

JCTVC-D106 High Efficient 1 byte fixed length coding for Low Complexity Entropy Coding – PIPE/V2F [Kazuo Sugimoto, Ryoji Hattori, Shun-ichi Sekiguchi, Yoshiaki Kato, Kohtaro Asai, Tokumichi Murakami (Mitsubishi)]

In this contribution, a entropy coding scheme, PIPE/V2F, for low complexity condition is proposed. The proposed scheme realizes 1 byte fixed length coding with higher coding efficiency compared to LCEC which is currently used for low complexity condition in HM-1. In the proposed scheme, V2F (Variable Length to Fixed Length) coders are used instead of the V2V (Variable Length to Variable Length) coder for PIPE, and all V2F coders are designed to generate 4 bit fixed length codes. Context adaptation is disabled to accelerate the entropy coding/decoding in the proposed scheme. The proponent implemented the proposed scheme on TMuC0.9, and simulations are conducted using common test configurations of low complexity settings. The proposed scheme reportedly achieves BD BR reduction 3.2% on average for random access case, and 4.1% on average for low delay case. The increase of decoding complexity is reportedly around 8% when compared to LCEC.

Comments:

- 8% decoding time increase is for LD, reportedly 9% for RA and 27% for intra. Encoding time is increased more significantly (up to 80% for Intra)
- Context adaptation of CABAC is disabled, however context update still is in operation as a bottleneck
- LCEC is also further optimized by contributions to this meeting
- Part of the gain could be due to the fact that LCEC currently is only restricted to 8x8 transform coefficients whereas the method (as from CABAC) uses up to 64x64.
- The bit rate for chroma is increased significantly, whereas luma is decreased.
- Would it be possible to further reduce complexity? Perhaps not.

The method appeared interesting–, and further study was recommended. This would (complexity-wise) bring the LC and HE operational points closer together. It is certainly desirable to improve the LCEC efficiency; ultimately, we would hope to need only one single entropy coder design.

JCTVC-D185 Simplified Context modeling for Transform Coefficient Coding [Hisao Sasai, Takahiro Nishi]

Comparing with the AVC specification, an increased number of context models is used in the latest HEVC specification. It is desired to avoid unnecessary increases of the implementation complexity. The number of context models affects the memory capacity requirements, especially for a hardware implementation, and the computational cost for the initialization of each context model. In this contribution, it is proposed that a simplified context modeling for significant map and last flag be used. The proposed modifications reportedly reduce the number of context models by 46% for the significant map and 75% for the "last" flag, with 0.1% to 0.2% coding loss relative to the TMuC0.9-hm anchor.

The approach shares significance map contexts for various block sizes; and defines last flag contexts commonly for groups of diagonal lines (not one for each).

It was remarked that some context models are not used anyway (according to the SW coordinator, this could be above 40%).

Further study, also in the relation to the context size discussed earlier, was encouraged.

JCTVC-D209 Cross-check report on Sharp entropy slices (JCTVC-D070) [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda]

JCTVC-D219 Unified scan processing for high efficiency coefficient coding [Thomas Davies]

This document proposes a modification of high efficiency configuration coefficient coding to reduce scan complexity and increase the opportunities for parallel encoding and optimization. The method uses a single deterministic scan pattern per block, and divides the coefficients into chunks of size 16 or less within the scan, each of which is processed in turn. It allows for an encoder to compute contexts for subsequent chunks in parallel with encoding the current chunk, in addition to the parallel context processing of JCTVC-C062. The technique can also be used in conjunction with Adaptive Coefficient Scanning, as described in JCTVC-A124. The simplified scan introduces small losses in the range of 0.0-0.2% for low delay and random access and 0.2-0.5% for intra coding.

- This replaces the adaptive diagonal scan, split significance and last scan
- The proposal uses a "unified chunk scan", with chunks of size 16 in zig-zag-order, scanned forward for significance and in reverse for sign.
- The main motivation is separation of coefficient re-ordering which is desirable

The modifications are very implementation specific; similar to other approaches that reduce compression efficiency based on implementation-specific arguments

Further study was recommended.

JCTVC-D226 Reducing the table sizes for LCEC [A. Fuldseth (Cisco)]

This contribution presents results for using a reduced number of tables in LCEC. In particular, the total table size for the last_pos_and_level syntax elements is reduced from 1120 bytes to 352 bytes. The associated BD BR loss is reported as 0.7%, 0.2%, and 0.1% for intra, random access, and low delay configurations, respectively.

- Not expected to give advantage in runtime, but table sizes (memory) are the main concerns
- Loss is highest for intra (where some improvements will be implemented)

Further study was recommended.

JCTVC-D261 Improvements on transform coefficients coding in LCEC [J. Xu, M. Haque, A. Tabatabai]

In this proposal, several techniques are presented to improve the performance of transform coefficient coding in Low Complexity Entropy Coding of HEVC. First, different sorting tables are used for different types of TU in the proposed algorithm. These sorting tables are trained, based on a separate set of video sequences from VCEG. Experimental results reportedly show that there are 1.7%, 0.7% and 0.2% BD BR improvements on average compared to TMuC0.9. There is reportedly no increase in complexity for the proposed algorithm. Second, run-mode adaptation using swapping tables is introduced to TMuC0.9. Third, the encoding of the entire TU with sizes of 16x16 and 32x32 is implemented with differentiated tables based on training.

- First element: Use different sorting tables for different block sizes 1.7/0.7/0.2% BR red Intra/RA/LD
- Second element: Use adaptive sorting for run mode 1.3/0.7/0.0%
- Third element: Encode large blocks by developing dedicated tables 2.7/1.5/0.2%

Further study was suggested, e.g., in a CE on LCEC.

JCTVC-D238 Removal of cabac_zero_word to simplify error detection in CABAC [Y. Matsuba, V. Sze (TI)]

Error detection is necessary for some applications as bit errors can occur during transmission. The contributor asserts that in AVC, the existence of cabac_zero_word makes the error detection very cycle consuming because decoder needs to scan all the inserted cabac_zero_words to determine whether an error has occurred. The purpose of the cabac_zero_word insertion, as asserted by the contributor, is to keep the proper rate of bins vs. bits at the frame level. This contribution proposes to remove cabac_zero_word from the rbsp_trailing_bits(), and recommends using the filler_data_rbsp() to achieve the desired bin vs. bit ratio, as the filler data RBSP is outside of the current slice_data NAL unit. The alleged benefit of the proposal is to reduce the cycles for error detection, and using filler data RBSP reportedly makes the implementation of byte stuffing process simpler, with lower implementation cost.

The contribution was noted, although this does not appear to be of high priority currently.

It may be noted that the filler data RBSP, as specified in AVC is a non-VCL NAL unit that affects the HRD differently than the slice data NAL units.

JCTVC-D241 Parallel processing friendly context modeling for significance map coding in CABAC [Jian Lou, Krit Panusopone, Limin Wang] (missing prior, uploaded Wednesday 19th, before meeting)

The scheme used in the current TMuC0.9 for CABAC significance map coding uses the nearest neighbors for context modeling from JCTVC-A116 in order to estimate the probability distribution. Significant dependencies are introduced which allegedly prohibit the parallelization of CABAC. This contribution document proposes a context modeling for significance map coding in CABAC that is asserted to be parallel processing friendly. The proposed scheme is implemented with zig-zag scan (see JCTVC-C114) and it reportedly could be extended to other schemes. The experimental results reportedly show that there is 0.2% to 0.4% bit rate increase while saving 6% to 9% of the encoding time.

The contribution appeared similar to submissions by Sony and Qualcomm (see CE11).

JCTVC-D243 Analysis of entropy slice approaches [V. Sze, M. Budagavi (TI)]

Low power and high frame rate/resolution requirements for future video coding applications make the need for parallelism ever more important. The CABAC entropy coding engine has been asserted to be a key bottleneck in the H.264/AVC video decoder. This contribution begins by describing the differences between regular slices, entropy slices and interleaved entropy slices. It then provides an analysis of these tools based on throughput, coding efficiency, implementation complexity and latency. Based on these metrics, "interleaved entropy slices" is recommended as a favorable approach for parallel CABAC processing due to its high throughput, low memory bandwidth, low latency and high coding efficiency.

- Increasing number of cores (at lower clock) helps to reduce power consumption – motivation for higher amount of parallelism
- Discusses regular slices, entropy slices (regular, serial, interleaved) w.r.t. tradeoffs of parallelism, coding efficiency, memory requirements, latency
- Investigation was suggested regarding whether there is a big penalty in compression efficiency when an ultra-large frame is divided into slices.

JCTVC-D311 Adaptive coefficients scanning for inter-frame coding [J. Song, M. Yang, H. Yang, J. Zhou, D. Wang, S. Lin, H. Yu]

This contribution proposes an adaptive scanning method for transform coefficients in inter-slices. A scanning mode for every Transform Unit (TU) is chosen based on the texture direction of a reference block and no flag is sent to the decoder side. The proposed technique was implemented on top of TMuC 0.9 and the comparison tests were done with the existing methods in TMuC 0.9 version. The performance of this new scanning order method is evaluated based on the common test conditions specified in JCTVC-

C500. Proposed method reportedly provides 1.1% and 0.4% improvements in high efficiency low-delay and random access configurations, respectively.

- Three scan directions: zig-zag, horizontal, vertical
- A new zig-zag scan is suggested (the usual zig-zag is not included) (which reportedly gives approximately 0.1% compression improvement)
- It was remarked that this introduces additional accesses and/or operations (gradient derivation) in the reference memory and does not give significant more improvement over other (more simple) scan adaptation methods that were reported.

JCTVC-D336 Reduced-complexity entropy coding of transform coefficient levels using a combination of VLC and PIPE [T. Nguyen, M. Winken, D. Marpe, H. Schwarz, T. Wiegand]

In this contribution, a method for coding of absolute transform coefficient levels for the high efficiency case is presented. The main underlying idea of this proposal is to allow the mixing of structured VLCs and PIPE/CABAC coded bits. Compared to the current method implemented in HM 1.0, the same coding efficiency is reported to be achieved while the computational complexity is reduced, especially for the high bit rate case. Also, the upper limit on the number of bins to be parsed by PIPE/CABAC can reportedly be reduced by at least a factor of 3 compared to the current method.

The range of levels is divided into three ranges: Low levels coded by CABAC, medium levels by truncated Golomb-Rice, high levels by EG0. For high levels, remaining bins for the absolute transform coefficient levels are coded in bypass mode. The following remarks were recorded in the discussion:

- Reduces the throughput compared to PIPE/CABAC (bins/pixel) from approximately 4.3 (anchor) to approximately 2.9 on average (maximum from 8.1 to 3.6), while the effect on compression is negligible (+/- 0.02)
- It was suggested that this could be seen as "putting CAVLC on top of CABAC"
- Encoding time is increased slightly (2-4%), decoding time is decreased (2-4%). The increase of encoding time is said to be an implementation issue.

The concept appeared interesting, and further investigation was recommended

JCTVC-D429 Cross-check results for HHI's Proposal JCTVC-D336 [Y. Zheng, M. Coban] (late registration Thursday 20th after start of meeting, uploaded Friday 21st, second day of meeting)

Confirmed by matching results.

JCTVC-D342 More improvements and results of the arithmetic coding based on probability aggregation [Hongbo Zhu] (missing prior, uploaded Wednesday 26th, near the end of the meeting)

This contribution was not available until the meeting was almost finished, and the presenter was not available at several times when a presentation opportunity was provided. Participants who are interested in studying the proposal should resolve any questions directly with the author.

JCTVC-D380 Reduced complexity PIPE coding using systematic v2v codes [Heiner Kirchhoffer, Detlev Marpe, Heiko Schwarz, Christian Bartnik, Anastasia Henkel, Mischa Siekmann, Jan Stegemann, Thomas Wiegand]

In this contribution, an entropy coding scheme is proposed that is based on the PIPE coding concept using variable-to-variable (v2v) codes. A set of nine so-called systematic v2v codes is designed and the probability interval partitioning is adapted accordingly. These systematic v2v codes can be efficiently implemented by using counters instead of using tables for storing the v2v codes. Experimental results reportedly show that the average number of operations per decoded bin can be reduced when compared to the binary arithmetic decoding engine of CABAC. In terms of coding efficiency, the presented set of systematic v2v codes shows an average BD rate increase of approximately 0.5% for the high efficiency configuration when compared to CABAC.

Three code classes:

- ‘unary to Rice’ codes which perform well for bins with probabilities in the range [0, 0.182)
- ‘three bin’ code which performs well for bins with LPB probabilities in the range [0.182, 0.248)
- ‘bin pipe’

Codes consist of a primary part and a secondary part. This allows the systematic behaviour.

The proposal was described as having lower complexity than the original PIPE design (one byte sufficient to store coding state, a lower number of operations per bin - less than half, less memory due to using systematic codes).

Still "two modes of operation" as in previous PIPE

Further study of the total complexity was suggested, e.g. looking at the comparison that was given in JCTVC-D106. It was suggested that combination with JCTVC-D336 would further reduce complexity.

The concept was considered interesting, and further study was recommended.

JCTVC-D383 Simplification of end-of-slice coding for arithmetic coding [F. Bossen (DOCOMO USA Labs)]

In this proposal, the coding of the end-of-slice flag is modified such that it is coded only when the end of a slice is reached. The decoder is modified such as to also rely on whether all bits in a coded slice have been ingested by the arithmetic decoder to determine the location of the end of the slice. With this modification it is possible to increase the granularity at which a slice can be terminated (e.g., 8x8) without increasing the number of bits required to encode the end-of-slice flag.

- Currently, the end of slice flag is sent at the end of each CU. The suggestion is to infer the end-of-slice flag at the decoder in such cases and use it only at the end of a slice.
- It was asked whether this increases the complexity of the encoder. After further discussion it was concluded that it apparently does not.
- This applies to both CABAC and CAVLC. One expert asserted that for CAVLC the inference could be more complicated.
- This was sugested to make sense for the case of finer granularity of slices where the overhead could become a little more significant.

The contribution also reported a bug – that the RBSP stop bit is encoded twice in the bitstream.

Decision: The bug should be fixed.

This was discussed further after clarification about slice status and offline communication with other experts (about possible complications of the inference approach).

Because we are currently staying at the LCU level for slice starting and ending position, it seemed that further consideration of this proposal was not necessary at this point. This should be further studied in the new CE4.

JCTVC-D186 Unification of Transform Coefficient Coding for non-reference intra block [Hisao Sasai, Takahiro Nishi]

A Separated DC coefficient coding for non-reference intra blocks is applied only in LCEC mode of the TMuC0.9-hm software. In this contribution, a unified solution on the non-reference intra block coding is proposed for both of the two entropy coders. In comparison with the TMuC0.9-hm anchors, the proposed change leads to no significant differences in BD BR and software execution time.

It was agreed that unification is desirable, but currently there are many differences and this one only resolves one point.

JCTVC-D452 Cross checking of JCTVC-D186 on unification of transform coefficient coding for non-reference intra block [A. Tabatabai, C. Auyeung (Sony)] (late registration Wednesday 26th after start of meeting, uploaded Wednesday 26th, near the end of the meeting)

This contribution provided cross checking results of JCTVC-D186 on "Unification of transform coefficient coding for non-reference intra block". Cross checking for Intra HE, Intra LC, RA HE, and RA LC were completed. The cross checking results reportedly matched the results provided by the proponent of JCTVC-D186. The cross-checking of LD HE, and LD LC was still ongoing when reviewed.

- The cross check did not report encoder/decoder run time.
- Current code does not reduce but rather increases the number of lines of code (by copying the same part from LCEC part to CABAC part)

Further study in an AHG was suggested in general for various methods for reduced-complexity in entropy coding (JCTVC-D106, JCTVC-D226, JCTVC-D336, JCTVC-D380, …).

17.13 Intra prediction and mode coding

JCTVC-D083 Non-directional intra prediction for coding efficiency improvement [Yongjoon Jeon, Seungwook Park, Byeongmoon Jeon]

The HM has up to 33 directional modes and 1 non-directional mode (which is the intra DC mode). At the previous meeting, it was suggested that having only 1 non-directional mode may be insufficient for accuracy on prediction units (PU) with complex texture. In this context, this contribution proposes a non-directional intra prediction scheme which uses the planar prediction of the TMuC but modifies it to reportedly be more efficient in terms of coding efficiency. In the proposed method, the current intra DC mode is replaced by the proposed non-directional intra mode. The proposed scheme reportedly achieves 0.5% and 0.7% for Intra High Efficiency and Intra Low Complexity configurations, respectively, and the maximum gain of 1.5% was reported for the Vidyo1 sequence under Intra Low Complexity configuration.

- Replacement of DC mode through a modification of planar mode: Perform prediction of bottom-right sample, bilinear interpolation, refinement by recursive filtering
- In contrast to original planar mode, residual is encoded
- Interesting gain
- Complexity-wise in terms of operations, this seems not to be significantly higher, however recursive filtering could be of concern
- Was applied to luma and chroma

JCTVC-D326 Planar intra coding for improved subjective video quality [J. Lainema, K. Ugur, O. Bici (Nokia)]

This document describes encoder modifications for planar coding with an aim to improve subjective quality when the planar intra coding is enabled in the HM 0.9 environment. Planar coding was initially included in TMuC, but it was decided in Guangzhou meeting to further study it and consider encoder decisions based on subjective quality. This contribution proposes the planar coding, but with an encoder algorithm to improve the subjective performance. Since planar coding is a tool to improve subjective quality, rather than objective quality, visual examples demonstrating the claimed benefit of planar coding are also included. Finally, restricting the block size of planar coded blocks is proposed to further improve objective results without affecting subjective quality.

- Decision on planar mode based on smoothness of the block (evaluation on DCT coefficients)
- Leads to objective losses, but claimed to give subjective gain
- Increases complexity of encoder (second DCT needed)
- Signalling at CU level for 16x16 and above, whole CU is the synthesized without residual encoding

JCTVC-D210 Study on Nokia planar intra prediction (JCTVC-D326) [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda]

JCTVC-D235 Enhancements to Intra Coding [Sandeep Kanumuri, TK Tan, Frank Bossen]

This contribution proposes two modifications to intra coding. The first modification is the introduction of a modified planar mode called planar+DST which codes the residual. The second modification changes the intra mode coding (IMC) by using up to two candidate modes derived from neighboring partitions. The proposed modifications reportedly improve the coding efficiency under all 6 common test conditions. For the High-Efficiency setting, the average reduction in luma BD BR is reported as 2.1%, 1.1% and 0.3% with Intra, Random-Access and Low-Delay conditions, respectively. For the Low-Complexity setting, the corresponding reduction is reported as 2.4%, 1.0% and 0.3%.

- Predict bottom-right pixel, perform bilinear interpolation to generate residual, encode residual by "DST type 4"
- Use HM "DCT" of double length, only odd basis functions
- Bilinear interpolation implemented by shifts/additions
- Mode is signalled
- A CABAC bug fix was found (Decision: Adopt)
- Using DCT instead of DST reportedly loses 0.4% for HE and 0.7% for LC
- Signalling at the PU level (as sub-mode of the DC mode i.e. DC mode still exists)
- Additional complexity at encoder 7-11% (mainly due to lack of fast RD in chroma)
- Another part of the proposal is to derive two most probable modes, and signal which one to use. This gives 0.8% BR reduction
- Include in CE on Intra prediction

JCTVC-D201 Cross verification of Docomo intra coding improvements (JCTVC-D235) [J. Lainema, K. Ugur (Nokia)]

Results confirmed; no cross-check performed on the "signaling of most probable mode" separately.

JCTVC-D166 Improved Intra Mode Coding [Mei Guo, Xun Guo, Shawmin Lei]

This contribution proposes an improved intra mode coding method, which includes two major parts: improved intra mode prediction (IIMP) and context dependent intra mode coding (CDIMC). In IIMP, the "most probable mode" of a luma block is adaptively selected from the modes of two neighboring blocks instead of directly using the one with smaller mode index in HM1.0. The prediction modes of chroma are also re-ordered, so that the mode which is equal to the corresponding luma mode has the shortest codeword. In CDIMC, the coding tree for the current block is adaptively selected from a set of pre-defined coding trees according to the modes of its neighboring blocks. Experimental results reportedly show that the proposed method can achieve an average bit-rate reduction of 1.6% and 2.0% for high efficiency all-intra (HE-AI) and low complexity all-intra (LC-AI), respectively. Encoding time increases are reported as 1% and 3% for HE-AI and LC-AI, respectively. Eecoding time increases are reported as 1% and 3% for HE-AI and LC-AI, respectively.

- Approach similar to JCTVC-D236 (signaling to use first or second most probable mode)
- Probability is derived from left/top mode combination
- Chroma mode further derived from luma mode (mode reordering)
- These two methods give 1.1%/1.2% BR reduction for HE and LC
- Context-dependent intra mode coding (from A-107) in addition, gives 0.8/1.5% BR reduction
- Total improvement as given above
- Investigate in CE

The contributors of JCTVC-D235 support adoption of the method for 2 most probable candidates and signaling. However, other experts expressed concern, as this was not yet investigated in a CE.

JCTVC-D147 Cross-verification report for MediaTek's (JCTVC-D166) proposal from Microsoft [J. Xu (Microsoft)] (missing prior, uploaded Tuesday 18th, before meeting)

JCTVC-D255 Improved Chroma Intra Mode Signaling [L. Dong, W. Liu, A. Tabatabai]

The intra coding of current HM uses "unified intra prediction". Depending on the PU size, the possible number of prediction modes for the luma component can be up to 34 (33 directions plus DC). For chroma components, there are 5 different modes regardless of the PU size (vertical, horizontal, DC, diagonal down right, and "same as luma"). This study reports that the "same as luma" mode is usually a good mode, but in the current implementation this mode is encoded using more bits than the other modes during entropy coding. Accordingly, this contribution proposes a modified binarization/codeword assignment for chroma intra mode signaling. Results reportedly show that with the proposed change a BD rate saving of 0.7% for all intra high efficiency and 0.6% can be achieved for all intra low complexity with no added encoder or decoder complexity. This result has been cross checked and confirmed.

- Similar to chroma mode derivation in JCTVC-D166
- Currently, the "most probable mode" (same as luma) is the longest codeword, it is suggested to use the shortest
- "Code space reduction" eliminating chroma mode which matches the MPM

JCTVC-D220 Cross verification of Improved Chroma Intra mode Signaling [Virginie Drugeon]

Confirmed that results match and the modification is minor.

JCTVC-D278 Improved Signaling and Binarization of Chroma Intra Prediction Mode [J. Dai, O. C. Au, F. Zou, C. Pang, X. Wen (HKUST)]

This contribution proposes a modified signaling and binarization method for Chroma Intra Prediction Mode. In current TMuC software, the U and V components share the same intra prediction mode, and five modes can be chosen. In the order of mode number, the five modes are: Vertical, Horizontal, DC, Down-right and Luma angle mode. It was reported that the current binarization of these five modes in Tmuc is not efficient, and a different signaling and binarization method was proposed. Experimental results reportedly show that RD improvement is achieved in AI configurations.

- Same as JCTVC-D255 again

Decision: Adopt solution of JCTVC-D255/JCTVC-D278/JCTVC-D166 (reported to be identical, also supported by the contributors of JCTVC-D350 from CE6).

[JCTVC-D426](#) Cross check report of HKUST's JCTVC-D278 Proposal [Carmen Cheng, Jenny Huo (ASTRI)] (late registration Thursday 20th after start of meeting, uploaded Friday 21st, second day of meeting)

Confirmed.

[JCTVC-D112](#) Evaluation of Most Probable Mode [Tomoyuki Yamamoto]

In this contribution, the effectiveness of Most Probable Mode (MPM) on TMuC 0.9 is reported. In addition, the effectiveness of MPM on TMuC 0.9 with the coding tool called Differential Coding on Intra Modes (DCIM) is reported. The results reportedly indicate that MPM introduces some gain when it is used with TMuC 0.9 coding tools. It is indicated that MPM causes some loss when it is used with DCIM.

- As both methods (MPM and DCIM) are targeting the same, this is not surprising
- Contribution meant as information

[JCTVC-D253](#) Improved Intra Mode Coding by Multiple Mode Candidates [Wenpeng Ding, Xiaoyin Che, Yunhui Shi, Baocai Yin] (missing prior, uploaded Monday 17th, before meeting)

In the Current TMUC software, a "most probable mode" is deduced to predict the intra modes. This contribution proposes to use multiple intra modes as prediction candidates. Several mode candidates are deduced from neighboring intra modes to improve prediction accuracy of intra modes. Experimental results reportedly demonstrate that the proposed method can improve the prediction accuracy from 23% to 34%. And the overall BD BR is reportedly reduced about 0.6% with AI LC configuration, 0.3% with AI HE configuration.

The reported gain is lower than reported in JCTVC-D235 and JCTVC-D166. The reason may be due to the different definition of remaining candidate(s).

[JCTVC-D199](#) Configurable directional intra prediction [J. Lainema, K. Ugur (Nokia)]

This contribution proposes signaling the number of available intra prediction directions for each PU size. The asserted motivation for this is to allow low complexity encoders achieve better compression efficiency and improve the adaptivity to different types of content.

By letting the decoder know that certain directions will not occur, BR reductions of up to 1.3% on HE and up to 4.1% in LC are reported when compared to an encoder that does not consider certain prediction directions. This would be signaled in the SPS. It is noted that the reference encoding used for comparison purposes was not the group-agreed encoding reference configuration.

This seems to be useful, but different approaches would be possible (what normative action of the decoder?). Further study was recommended.

[JCTVC-D109](#) LUT-based adaptive filtering on intra prediction samples [Kazuo Sugimoto, Shun-ichi Sekiguchi, Akira Minezawa (Mitsubishi), Kazuhisa Iguchi, Yoshiaki Shishikui (NHK)]

In this contribution, an adaption of filtering on intra prediction samples is proposed to improve the coding performance. In the proposed scheme, the prediction samples generated by unified intra prediction are filtered just before generating residual samples according to the prediction unit size and the intra prediction mode. The proposal was implemented on TMuC0.9, and simulations are conducted using common test configurations with Class A-E sequences and SHV sequences cropped to Class A size. The proposed scheme reportedly achieves up to 1.3% (0.7% on average) BD BR reduction for high efficiency, and up to 4.6% (1.6% on average) BD BR reduction for low complexity AI configuration, respectively. A simplified version of the scheme is also proposed in this contribution.

- Applied to PU sizes up to 16x16

- Increased encoding time 2% for HE, 8% for LC; decoding time increased 4% for LC
- Simplified version with negligible change in time 0.3% / 0.5% BR reduction
- Simplified version with SAIS (C234) 0.5% / 1% BR reduction

JCTVC-D171 Improved AIS filter [M. Budagavi (TI)]

Adaptive Intra smoothing (AIS) has previously been tested using [1 2 1] filtering. This contribution presents results of an AIS scheme using a different filter [1 1 4 1 1] which was asserted to emphasize high frequency and edge information. For Intra only coding, the filter [1 1 4 1 1] reportedly provides a coding efficiency improvement of 0.1-0.2% BD BR. This coding gain is on top of the 0.3-0.7% gain shown by AIS with filter [1 2 1] for Intra only conditions.

- Gain 0.2% for HE and 0.1% for LC
- 2 more additions, two more shifts per pixel

JCTVC-D391 Improvement of Adaptive Intra Smoothing by Switching Interpolation Filters [E. Maani, A. Tabatabai]

This document describes a method to improve the performance of Adaptive Intra Smoothing algorithms. In this method, a set of new 4-tap interpolation filters is proposed to be used in the Intra prediction process instead of the linear interpolation when Intra smoothing is set to off. The method in tested on hybrid Intra smoothing and reportedly showed, on average, 0.3% and 0.4% improvements over some prior results for HE and LC settings, respectively.

- Gain is compared to the setting "AIS on"
- Encoding and decoding time for LC increased by 2-3%

Continue CE on intra smoothing within the intra prediction CE

JCTVC-D094 Constrained Intra Prediction Scheme for Flexible-Sized Prediction Units in HEVC [Viktor Wahadaniah, ChongSoon Lim, Sue Mon Thet Naing, Xuan Jing]

This contribution provides an investigation report on the possible improvements of a constrained intra prediction scheme in HEVC. By adapting the constrained intra prediction scheme to the characteristics of HEVC video coding scheme, in particular the flexible-sized prediction units, experimental results reportedly show average BD BR differences over AVC-style constrained intra prediction scheme of 0.2% (Y), 0.5% (U), 0.5% (V) for random access high efficiency setting, 0.2% (Y), 0.3% (U), 0.3% (V) for random access low complexity setting, 0.1% (Y), 0.2% (U), +0.1% (V) for low delay high efficiency setting, and 0.1% (Y), 0.1% (U), 0.2% (V) for low delay low complexity setting. The contribution suggested that the coding efficiency loss introduced by the AVC-style constrained intra prediction scheme can be further reduced by considering HEVC characteristics in the constrained intra prediction design. It was firstly recommended to include the functionality of constrained intra prediction into HEVC. It was also recommended to conduct further investigation on the suitable constrained intra prediction design for HEVC.

- Refers to JCTVC-D086 (constrained intra prediction when decoder-side memory compression is applied) which uses AVC-style constrained intra prediction
- Prediction defined conditional to availability of reference blocks (padding of missing pixels by interpolation or extrapolation)
- Gains compared to the AVC-style CIP 0.1-0.2%; actual loss against anchor around 2%.

JCTVC-D386 Constrained Intra source code implementation [Rickard Sjöberg, Jonatan Samuelsson (Ericsson)] (v1 incomplete without results)

Constrained Intra prediction is a well-known and well-used concept in AVC. Although Constrained Intra has been part of all the TMuC and HM specifications it has not so far been implemented in the TMuC or HM source code. This paper presents an implementation of Constrained Intra in HEVC.

- Reports that the method of AVC is not directly applicable
- Same scheme as proposed in JCTVC-D094
- Constrained intra prediction is currently in the WD, but not described

Relation to slice development: CIP is mostly useful in a lossy environment, when slice structures are used. The case of lossy compression at decoder memory is not the relevant use case.

Further study was recommended; this will certainly be needed, but is not a high priority currently, as the intra prediction schemes are still under development. It is also not possible to directly use the scheme from AVC, as this would need to be changed from MB structure to CU structure.

Note: Refer to JCTVC-D086 which is adopted as "pure AVC style" from track A and subsequent plenary discussion.

JCTVC-D193 Integration into the TMuC of an Intra Prediction based on a linear combination of Template Matching predictors [Ronan Boitard, Laurent Guillo, Tangi Poirier]

This document presents an intra prediction method based on a linear combination of three template matching predictors and the results once integrated into the TMuC 0.9. The resulting design reportedly always improves the intra prediction. The average BD rate gain for the High Efficiency configuration is – reportedly 0.8% and the maximum gain for a sequence is 2.2%. With this proposal, the complexities of the encoder and the decoder are reported as, respectively, 130% and 123% in comparison to the TMuC 0.9.

- For LC, increase is 41% at encoder and 44% at decoder.
- The scheme appears too complex for the amount of coding efficiency improvement that it provides.

JCTVC-D251 Intra prediction based on repetitive pixel replenishment with adaptive block size [Kenichi Iwata, Seiji Mochizuki, Ryoji Hashimoto]

This contribution presents evaluation results of intra prediction by template matching with adaptive block size based on repetitive pixel replenishment (Intra RPR). The simulation results reportedly show that this proposed technique has an average of 1.8% (Y), 1.4% (U), and 1.3% (V) BD BR improvement against TMuC 0.9. BD BR improvement from the proposed scheme is up to 5.0% (Y), 4.1% (U), and 4.1% (V).

- New aspects: adaptive block size, fractional pixel position, modified VLC table for intra motion vector
- Padding method for cases where reference block contains unavailable pixels
- Encoding time: 381% (Intra), 203% (RA)

The encoding time seems much too high. Decoder complexity is also increased - uses same interpolation filter as in motion compensation.

JCTVC-D283 Further Encoder Improvement of intra mode decision [Liang Zhao, Li Zhang, Xin Zhao, Siwei Ma, Debin Zhao, Wen Gao]

Based on JCTVC-C207 which was reportedly adopted in the last JCT-VC meeting, this contribution presents a further simplification of the encoding scheme for unified directional intra prediction. Experimental results reportedly show the proposed scheme to provide 14% time savings in intra high efficiency testing and 20% time savings in intra low complexity tests on average compared to the current default encoding scheme in HM 0.9 with almost the same coding efficiency.

- Approach: Rough mode decision with reduced set of candidates
- MPM always one of the candidates
- Configuration S3: BR Change 0.004% for HE, 0.04 for LC; encoding time reduced by 14% and 20%.
- Configuration S5: BR saving -0.13% for HE, -0.21% for LC with roughly 5% decrease in time

Decision: Adopt "Configuration S5".

JCTVC-D436 Crosscheck of Peking University's proposal (JCTVC-D283) [M. Guo, X. Li, X. Guo (MediaTek)] (late registration Saturday 22nd after start of meeting, uploaded Sunday 23rd, fourth day of meeting)

Cross-check confirmed.

JCTVC-D287 Bi-Intra Prediction using slope information [Chan-Won Seo, Jong-Ki Han, Jeong-Yeon Lim, Jin-Han Song]

This contribution presents bi-intra prediction scheme which is used with offset and reference smoothing. Since the proposed technique considers the concept of slope and uses bi-prediction like bilinear interpolation, it was asserted to improve the coding efficiency of HM. In this document, experimental results under the common test condition defined by JCTVC-C500 were reported. For I slice only coding structure, the average BD BR gains are reportedly 2.4% on low complexity condition and 0.7% on high efficiency condition. Based on the results presented in this contribution, the contributor recommended this tool to be studied and discussed in a CE.

- Method to 1) compute the last line/column of a block (taking into account an offset computed from available neighbor blocks), 2) perform directional Bi-prediction from first/last line/column, 3) perform smoothing of reference
- Encoding time was increased by 50%, decoding time by <5%

The proposal appears to show similar gains as in other methods of B prediction (from CE). Also there appeared to be some similarity with JCTVC-D083 and JCTVC-D235. The offset correction aspect seems to be different.

JCTVC-D300 Improved Intra prediction for positive directions in UDI [Y. Lin, C. Lai, J. Zheng, L. Liu]

This document presents an Intra prediction for positive directions in UDI. Both the reference pixels from main and side arrays are used. The prediction value of a particular point is linearly interpolated from two reference points. Simulation results reportedly show 0.3% and 0.4% bit-rate reduction over HM0.9 anchors for Intra and Intra LC configurations with approximately the same encoding and decoding time.

This is only used in the 45-degree direction (mode 6). It includes 2 multiplications and a division implemented by lookup table. Similar to JCTVC-D108.

Even though the increase in encoding and decoding runtimes seems to be low, adding complexity in only one mode does not seem favorable for hardware implementation, a decoder must take into account the worst case in terms of complexity (as it could be that this mode is always used).

Bi-prediction will be further investigated in the CE; the contributors are encouraged to identify the commonalities and benefits w.r.t. other methods.

JCTVC-D302 Intra coding improvements for slice boundary blocks [Y. Lin, C. Lai, J. Zheng, L. Liu]

This proposal presents two modification of Intra coding for the boundary blocks of a slice or picture, including Intra prediction mode coding and reference pixel padding. Firstly, bit spending for Intra prediction mode coding is changed by reducing the number of the candidate Intra prediction modes. Secondly, "unavailable" reference pixels for boundary blocks are padded with the closest value from an available neighbor block, instead of a fixed DC value. The test results reportedly show 0.5% and 0.4% bit-rate reduction for Intra and Intra LC configurations with almost the same encoding and decoding time.

Gains reported are for the case of slices with 1500 bytes maximum size.

The method becomes useful only in the context of slices. Further study in the same context as JCTVC-D094 and JCTVC-D283 is suggested: Same or similar padding approaches are suggested there – it would not be useful to define too many different building blocks in a decoder design.

JCTVC-D148 Cross-verification report for Huawei's (JCTVC-D300 and JCTVC-D302) proposal on intra coding from Microsoft [J. Xu (Microsoft)] (missing prior, uploaded Tuesday 18th, before meeting)

17.14 Transforms and Residual Coding

17.14.1 Core transform implementation

JCTVC-D036 Matrix multiplication specification for HEVC transforms [M. Sadafale, M. Budagavi (TI)]

This contribution is a continuation of prior work presented in JCTVC-C226 and presents more details and software optimization results. JCTVC-C226 proposed the use of matrix multiplication to specify HEVC transforms. Matrix multiplication has the advantage that it is friendly to parallel processing with minimal dependency and control logic. In hardware, matrix multiplication results in low-area architecture, while in software it reportedly leads to efficient implementation on SIMD processors. Matrix multiplication allegedly has better fixed-point behavior than Chen’s DCT/IDCT which is asserted to allow for elimination of existing norm correction matrices in HM. The memory requirement for storing norm correction matrices in the TMuC decoder reportedly goes down from 7.5 KB to 6 bytes. The corresponding memory requirements in the TMuC encoder reportedly goes down from 7.5 KB to 12 bytes. A fixed-point version of a matrix multiplication pseudo DCT/IDCT along with norm correction matrix elimination optimization was implemented in TMuC-0.9. Simulation results reportedly indicate that matrix multiplication DCT/IDCT achieves similar coding efficiency performance when compared to TMuC-0.9 with a Chen-style pseudo DCT/IDCT (Average BD BR: 0.1 to -0.3%). TMuC-0.9 decoder and encoder with matrix multiplication DCT/IDCT implemented with even-odd decomposition optimization have run times that are comparable to TMuC-0.9 with Chen’s implementation. Decoding time ratios on the same PC are reportedly in the range of 99%-100% range. Encoder time ratios on heterogeneous Linux cluster reportedly range from 93%-107%.

- With IBDI off, the current HM implementation of IDCT reportedly requires 21 bits, whereas matrix mult. reportedly requires 15 bits. With IBDI on, 25/19 bits (case of 16-size transform)
- Butterfly structures have cascading of multipliers, such that they cannot be parallelized and incur latency (at least if there is rounding between the stages)
- In effect, this may mean that matrix multiplication can be faster than "fast" algorithms (particularly in hardware)

Some doubt was expressed that the estimate of bit depth in HM may be pessimistic and could be different by other implementation. It did not seem fully clear how to measure the bit depth and latency. A comment was that measuring latency must take into account pipelining and the number of available multipliers.

The best selection would also depend on target platform architecture. Compromises will be necessary.

JCTVC-D245 Verification of TI's proposal on matrix multiplication architecture for DCT/IDCT [Jian Lou, Limin Wang]

JCTVC-D224 Unified transform design for HEVC with 16 bit intermediate data representation [A. Fuldseth, G. Bjøntegaard (Cisco)]

This contribution proposes a set of transforms for HEVC, covering all transform sizes from 4x4 to 32x32. The proposed transforms are intended to replace the existing transforms specified in HM1.0. The proposed transforms have the following properties; 16 bit data representation before and after each transform stage (assuming 8-bit input data and IBDI disabled), no need for correction of different norms of basis vectors during quantization/dequantization, all transform sizes above 4x4 can reuse arithmetic operations for smaller transform sizes, and implementations using either pure matrix multiplication or a combination of matrix multiplication and butterfly structures are possible. The proposed transforms are implemented without transform precision extension (TPE) and compared with the existing transforms with TPE=4 (anchor conditions). Average BD BR gains were reported, varying between 0.1% and 0.6% depending on the test condition (low complexity/high efficiency, intra/random access/low delay).

- The basis vectors are almost orthogonal and have almost equal norms, so no quantization/dequantization matrices are necessary (same quantization for all transform sizes)
- 8 bit representation of transform coefficients is enabled, with a bit width of accumulators for matrix multiplication of less than or equal to 32 bits.
- Scaled transform coefficients are very close to DCT coefficients
- Large transforms partially re-use smaller transforms, such that a "partial butterfly" is possible
- 4x4 and 8x8 were also changed

Clarification was requested regarding what a "partial butterfly" means. It seems it is not possible to fully decompose these matrices (log2N). In the ideal case, a fast transform algorithm should be capable of implementation by both matrix multiplication and "fast" implementation.

Gain was reported (0.1 or 0.2% bit rate reduction compared to HM). It was not clear what the source of this gain was (perhaps the change of 4x4 and 8x8 transforms).

JCTVC-D268 Verification of Cisco transform proposal (JCTVC-D224) [M. Budagavi (TI)]

JCTVC-D339 Fast, Mult-Free Transforms for the HM [Wei Dai, Madhu Krishnan, Pankaj Topiwala] (initial uploaded versions had problems)

The current HM (0.9) uses integer transforms of sizes 4-pt to 32-pt, designed using Chen's factorization of the DCT, which provide good decorrelation performance and moderate complexity. This contribution discusses integer transforms and several variants, which reportedly offer substantial computational savings with effectively no performance loss. The current 4-pt and 8-pt transforms are initially retained, while the more complex 16-pt and 32-pt transforms are simplified, including multiplication-free designs. The multiplication-free designs reportedly provide the lowest complexity as well as exact invertibility in limited bitdepth arithmetic, yet reportedly have identical performance. A CE was proposed to further study and finalize these designs, and corresponding quantization structures. The transform itself was developed jointly with Samsung, and is presented in a joint proposal JCTVC-D365.

- Lifting implementation, allows perfect inversion
- Reports minor deviations (+/- 0.02%) in bit rate
- Transform is not orthogonal, quantization was adapted (see JCTVC-D365)
- The whole dynamic range (down to QP=0/1 with worst-case input) should be checked in the investigations

JCTVC-D037 DCT+Hadamard large transform [M. Budagavi, A. Gupte (TI)]

This contribution is a continuation of prior work presented in JCTVC-C226 and JCTVC-C255 and presents more details and software optimization results. JCTVC-C255 proposed a class of transforms for large block sizes which is a combination of DCT+Hadamard transforms for reducing computational complexity. When DCT+Hadamard is applied to only 32x32 Inter blocks, the average BD BR degradation is reportedly in the range of 0.2-0.4%. When DCT+Hadamard is applied to both Inter and Intra blocks, the average BD BR degradation is reportedly in the range of 0.4-0.8%. The 1D DCT+Hadamard transform involves application of two size-N/2 DCT transforms instead of one size-N DCT transform, resulting in reduction in number of multiplications required. There is reportedly a 50% reduction in number of multiplications for DCT+Hadamard implemented with matrix multiplication and 24% reduction in number of multiplications for DCT+Hadamard implemented with Chen's algorithm.

The contribution proposed a combination of DCT-16 followed by Hadamard-2.

Loss in compression is up to 0.8/0.9% BR increase in all-Intra coding; less in inter.

It appears that this loss does not justify the savings in complexity. In effect, this loses the advantage of 32x32 blocks, as the error would concentrate at the boundaries of the 16x16 transform.

JCTVC-D371 Crosscheck of TI's matrix multiplication specification (JCTVC-D036) and DCT+Hadamard large transform (JCTVC-D037) by Qualcomm [R. Joshi, Y. Zheng, J. Sole]

JCTVC-D388 Cross check of JCTVC-D037 on DCT+Hadamard large transform [C. Auyeung]

JCTVC-D256 Efficient 16 and 32-point transforms [R. Joshi, Y. Reznik, J. Sole, M. Karczewicz]

This contribution proposes new 16 and 32-point transforms. The proposed transforms are scaled orthogonal integer transforms and support a recursive factorization structure. The proposed 16 and 32-point transforms use 36 and 92 multiplications, respectively, compared to 44 and 116 multiplications for the corresponding transforms in the existing test model. A multiplication-free implementation for the proposed transforms is also provided. The BD BR performance of the proposed transforms is reportedly nearly identical to the existing transforms.

- 12 distinct scale factors for quantization for the 32x32 transform
- No significant change in coding efficiency
- Bit precision is bitdepthvideo+4bitsIBDI+9+5+5 for 2D transform (in the case of 10-bit video this would be larger than 32 bit)

JCTVC-D079 Verification of Qualcomm's proposal on alternative large transform architecture [C. Yeo, Y. H. Tan, Z. Li (I2R)]

JCTVC-D269 Verification of Qualcomm transform proposal (JCTVC-D256) [M. Budagavi (TI)]

JCTVC-D257 Low complexity 32×32 transform by partial frequency transform [J. Sole, R. Joshi, M. Karczewicz, Y.-M. Hong, M.-S. Cheon, I.-K. Kim]

This proposal presents an approach to simplifying the 32×32 transform by computing only the 16 lowest frequency coefficients in each direction. This simplification reportedly reduces the number of multiplications by 74% while reducing the intermediate buffering requirements by 50%. The loss in terms of BD BR for the high efficiency intra, random access, and low-delay configurations is reported as 0.31%, 0.22%, and 0.21%, respectively. There is no reported impact on the BD BR for the low complexity configuration.

- Combination of JCTVC-C209 and JCTVC-C237

- Loss in performance, roughly 0.3% BR increase
- Same quantization matrix used (norms of the basis vectors are the same)
- Question: 32x32 is not used often, is the loss higher for specific sequences? Not remarkable, highest loss around 0.7 or 0.8.
- A remark was given that even a small loss may be dangerous as it indicates a deviation of the transform basis characteristics. Particularly for large transforms, ringing may be a danger.
- Would be advisable to perform viewing. It was suggested that we may wish to find special test images for this.
- Some people expressed a concern that losses such as 0.3-0.4% could be unacceptable.

JCTVC-D135 Crosscheck of Samsung and Qualcomm's Partial Frequency Transform by MediaTek [Tzu-Der Chuang, Ching-Yeh Chen, Yu-Wen Huang]

JCTVC-D365 Fast Integer Transforms for the HM, and Complexity Analysis [Y.-M. Hong, I.-K. Kim, K.-H. Lee (Samsung), W. Dai, M. Krishnan, P. Topiwala (FastVDO)]

The current HM (TMuC-0.9) uses integer transforms of sizes 4-pt to 32-pt, designed using Chen's factorization of the DCT, which provide good decorrelation performance with moderate complexity. This contribution summarizes the performance and the complexity of the existing transform cores and describes some integer transforms and several variants, which reportedly offer substantial computational savings with effectively no performance loss. The current 4-pt and 8-pt transforms are initially retained, while the more complex 16-pt and 32-pt transforms are changed, including multiplication-free designs. The multiplication-free designs afford exact invertibility in limited bitdepth arithmetic, yet reportedly have identical performance. In addition, a simplified approach to quantization matrices was suggested – just replacing them with scalar values. This can reportedly be done for both the existing HM transforms, as well as the new transforms in the proposed design. The contributors asserted that the transform and quantization designs in the HM can be significantly improved computationally, with no noticeable loss of performance.

No quantization matrix was proposed for 16x16 and 32x32; only scaling according to QP value.

JCTVC-D129 Verification results of Samsung's proposals on Low-complexity transforms [Jungsun Kim, Byeongmoon Jeon] (missing prior / placeholder, uploaded before meeting)

JCTVC-D408 Crosscheck of Samsung and FastVDO's proposal JCTVC-D365 on simplified quantization/dequantization matrices [Xin Zhao, Li Zhang, Siwei Ma, Wen Gao] (missing prior, uploaded Tuesday 18th, before meeting)

JCTVC-D435 Cross verification of JCTVC-D365 by Nokia [K. Ugur (Nokia)] (late registration Saturday 22nd after start of meeting, uploaded Thursday 27th, near the end of the meeting)

JCTVC-D071 On transform dynamic range [Kiran Misra, Louie Kerofsky, Andrew Segall] (missing prior, uploaded Wednesday 19th, before meeting)

The dynamic range of an inverse transform is a critical parameter influencing the minimum width of the bus required between the processing unit which carries out the transform and the memory used to store results. Additionally it determines the total size of the memory used for storage and number of coefficients which can be pre-fetched with a single instruction. In this proposal a technique is described which reduces the required transform dynamic range to achieve a reduced dynamic range of 16-bits. This goal is reportedly achieved with an increase in the average Y Bjøntegaard Delta (BD) bit rate between 0.0%. and 0.2%. The performance was measured with all the tools in their default test settings, for e.g. there is an internal bit depth increment of 4 for the HE case, the transform precision extension is turned on for the low-complexity case etc. The transform dynamic range limitation is achieved by downshifting to restrict the bit-depth of coefficients being stored in memory (a) prior to being input to the first inverse 1-D transform and (b) at the output of the first 1-D inverse transform. A combination of QP period based scaling, clipping and transform size dependent bit shifts are used to achieve the 16-bit dynamic range.

- Clipping at the decoder was discussed. In practice, some encoders may not perform clipping.
- It should be clarified how this would be described in the standard.
- Several experts think this is a good idea, and recommended further study.

Discussions and Conclusions

A breakout activity was established (coordinated by P. Topiwala) on issues of transform implementation. In that activity, the main discussions were about measures for complexity.

It was suggested to establish a CE on core transforms and related quantization, with further discussion in a BoG (see JCTVC-D445):

- Complexity parameters (number of op's, bit depth, parallelism etc.)
- Performance (also visual investigation particularly for ringing)
- Fitness for implementation on different platforms (software/hardware/SIMDetc.)
- Complexity of quantization

The current HM uses quantization matrices for 16x16 and 32x32 which are consisting of almost equal entries, and it was asked whether these should be changed to equal values or replaced by a scalar value. According to JCTVC-D365, this would not affect performance. It is agreed to wait with this until other transform issues will be decided.

17.14.2 Alternative transforms

JCTVC-D048 Low-Complexity 4-point Integer Discrete Sine Transform [C. Yeo, Y. H. Tan, Z. Li (I2R)]

In this proposal, a method for performing a multiplier-less 4-point integer discrete sine transform is presented. In previous proposals, it has reportedly been shown that the mode-dependent directional transform can be carried out using an appropriate combination of discrete cosine transform and discrete sine transform. However, the discrete sine transform is carried out using fixed-point arithmetic. Here, an integer approximation of the discrete sine transform that is exactly orthogonal is presented. Furthermore, the resulting integer transform can reportedly be implemented without any multiplications. Experimental results reportedly show that the proposed integer transform has compression performance that is similar to the higher precision fixed-point arithmetic implementation.

- Results similar to JCTVC-D286
- DST type III (quarter of sine)
- BR reduction for intra: 1.3% / 2% for HE and LC
- Can be implemented by 15 adds and 6 shifts
- Results reported are using 4-point and 8-point DST, 8-point does not have fast algorithm

JCTVC-D286 Simplified multiplierless 4x4 DST for intra prediction residue [Xin Zhao, Li Zhang, Siwei Ma, Wen Gao]

In this contribution, a simplified 4x4 discrete sine transform (DST) scheme for intra prediction residuals is proposed. The proposed 4x4 pseudo DST is implemented integer transform matrix, multiplierless arithmetic and has low dynamic range of internal results. Also a mode-dependent coefficient scanning method is proposed together with the proposed DST.

- 4-point DST identical to JCTVC-D048 (except sign inversion)
- 8-point integer transform is a KLT computed from covariances of horizontal/vertical prediction errors
- Mode-dependent coefficient scanning
- HE intra results: 1.8% for luma with MD scanning, 1.0% without scanning

It was commented that, for this 8-point transform (KLT), no fast algorithm exists, but there could be chances to find one similar to a DST.

JCTVC-D182 Performance report of adaptive DCT/DST selection [Atsuro Ichigaya, Shinichi Sakaida]

This document describes the coding performance of an adaptive DCT/DST selection method on HEVC test Model (HM) 0.9. In this proposed method, DST is used as an additional transform for intra and inter coding blocks in JCTVC-A122. DCT and DST are selected adaptively according to input signal characteristics without any training. Adaptive transform selection to the luma signal is implemented in HM0.9 and the performance is evaluated in this document. The coding results reportedly show BD BR reduction averaging 0.8% for low delay LC condition is achieved.

- DCT and DST type II (half period of sine), symmetric basis can be implemented by fast algorithm
- Almost same algorithm can be used for both transforms
- Either 2D-DST or 2D-DCT is used for all block sizes; usage is signalled. No mode dependency.
- Coding results: Intra/RA/LC HE 0.5/0.6/0.6%, LC -0.1/0.3/0.8%.
- Encoding time significantly increased (60%) for intra, as both transforms need to be computed and compared for mode decision

JCTVC-D180 (m18935) CE7: Hardware Friendly Rotational Transform [Xing Wen, Oscar C. Au, Lin Sun, Jiali Li, Feng Zou, Chao Pang, Jingjing Dai]

Notes below JCTVC-D222.

JCTVC-D222 Performance of Rotational Transform (ROT) in TMuC 0.9 [Xing Wen, Oscar C. Au, Lin Sun, Jingjing Dai, Feng Zou, Chao Pang]

(Both contributions presented jointly; JCTVC-D222 is the result of TMuC ROT.)

The 8x8 Rotational Transform (ROT) is a secondary transform after DCT and is implemented in the HEVC Test Model (HM) software. Although ROT can reportedly achieve superior coding efficiency compared to only using a DCT-like transform, it was reported that the original ROT design cannot be efficiently implement by hardware. In this proposal, a different rotational transform (HF-ROT) is proposed which can reportedly achieve similar coding efficiency gain and also can be easily implemented by hardware. Four HF-ROT modes were proposed.

- Results: 0.1-0.2% BR increase compared to original ROT from previous TMuC
- BR reduction compared to anchor: Intra 2.4/3.2%, RA 1.1/1.2% for HE/LC
- The contribution reports a very significant increase in encoding and significant increase in decoding time, but this is said to be unreliable.
- Some concerns were expressed whether the analysis of clock cycles necessary for ROT is correct.

- It was questioned why the compression performance is reduced, while other proposals for fast ROT do not report such degradations.

JCTVC-D276 Rate-Distortion Optimized Transforms for Intra Block Coding [F. Zou, O. C. Au, C. Pang, J. Dai, X. Zhang, X. Wen (HKUST)]

This contribution proposes a rate-distortion (RD) optimized transform scheme for NxN TU in HM0.9. The transform pairs are trained off-line and implemented using matrix multiplication in HM0.9 based software. This technique reportedly achieves 3.2% BD BR improvement in Intra Low Complexity (LC) conditions and 2.0% BDBR improvement in Intra High Efficiency (HE) conditions.

- The algorithm to optimize transform is a kind of least-squares optimization plus lambda-penalty for transform coefficient energy for RD term (for lambda=0 this would be SVD)
- A very significant increase in encoding time and a significant increase in decoding time (25%) were reported.

As it appears that this scheme must be directly inplemented as a 2D transform, it seems too complex.

JCTVC-D425 Cross-check report of HKUST's proposal JCTVC-D276 by ZJU [X. Zhu, S. Li, (ZJU)] (late registration Thursday 20th after start of meeting, uploaded Thursday 20th, first day of meeting)

JCTVC-D151 Mode Dependent 2-step Transform for Intra Coding [Youji Shibahara, Takahiro Nishi]

This contribution proposes a unification of MDDT and ROT, in which a mode dependent 1-step transform is used for 4x4 transform blocks and mode dependent 2-step transforms are used for larger ones. The same 4x4 mode dependent KLT as MDDT is used for 4x4 transform blocks. The first one of the 2-step transform is either the AVC transform or a Chen-DCT in the TMuC0.9-hm, and the second one is 4x4 KLT which is partially applied only for the lower frequency components. Application of the second transform is depending on the intra prediction mode of the corresponding prediction unit. An experimental result reportedly shows that the proposed method provides 1.3% and 0.6% gain for Intra HE and Random Access HE, respectively, over the TMuC0.9-hm anchors. The encoding time (and decoding time) is 103% (101%) for Intra HE and no major difference was reportedly observed for Random Access HE.

- A second transform is applied to a subset of coefficients, applied to all block sizes up to 32x32, always with a 4x4 size of second transform
- Quantization was not changed
- This approach could give a way to define a mode-dependent ROT
- It was recommendation to include this in a CE (along with ROT) to find commonalities (also in terms of complexity reduction)

JCTVC-D049 Mode-Dependent Coefficient Scanning for Intra Prediction Residual Coding [C. Yeo, Y. H. Tan, Z. Li (I2R)]

In this proposal, a method for the scanning of intra prediction residual coefficients is presented to improve rate-distortion performance of intra coding. While prior work in mode-dependent coefficient scanning has shown similar gains, they reportedly greatly increase the decoding complexity, since the scans are adaptive and residual coefficients statistics have to be update as each block is decoded. Furthermore, due to the arbitrary scan orders that are used, parallelization of the coding process may be difficult. The method in this contribution attempts to overcome these difficulties by using a simplified set of scans that lend themselves well to parallelization, and requires no statistics updating. Experimental results reportedly show that the proposed method has similar compression performance to adaptive scans while requiring much less decoding complexity.

- Result: -0.9% Intra HE, +0.1% Intra LC
- Four scans (2 different diagonal)
- Otherwise same as JCTVC-D360/JCTVC-D393

JCTVC-D447 BoG Report on Alternative Transforms [R. Cohen, C. Yeo, R. Joshi, F. Fernandes] (BoG report registered Monday 24th after start of meeting, uploaded Monday 24th, fifth day of meeting)

A BoG on alternative transforms met on the afternoon of Monday, Jan. 24 to discuss what should be done in the CE that follows from the work done in CE7: Alternative Transforms. Approximately 20 people attended the meeting. The goals of the upcoming CE are to investigate the compression efficiency and the additional complexity associated with each alternative transform. The main topics of discussion during this BoG meeting were the list of tools to include in the CE and which complexity metrics to use. A draft of the CE description that includes notes from the BoG meeting was appended in the document and was presented in the Track B session Wednesday afternoon.

17.15 IBDI and Memory Compression

JCTVC-D152 Adaptive scaling for bit depth compression on IBDI [T.Chujoh, T.Yamakage (Toshiba)]

In this contribution, a bit depth compression on IBDI and a definition for standardization were proposed. This contribution reportedly improves coding efficiency by increasing internal precision while minimizing reference frame memory access bandwidth. There are two points in the contribution.

- For the first aspect, an adaptive scaling method with a fixed length format was proposed, and secondly, a definition of distortion for memory compression was introduced.
- In the second aspect, a solution for fixed rounding problem that was pointed at previous meeting is shown.

The degradation introduced by fixed rounding is reported to be very significant in the Class E LD configurations (27% relative to IBDI usage).

The contribution reported that there are two ways that fixed rounding has been implemented in software, and the reference used for the fixed rounding comparisons was modified to use the one that is better ("Eq.2", from KTA software) on average.

As experimental results, the BR loss for the proposed method reportedly averages 0.7% for bit depth compression on IBDI, for fixed rounding the loss is reportedly 1.9%, and for using neither one the loss is reportedly 2.9%.

The overall benefit, relative to fixed rounding, was reportedly 1.2% (using a luma measure – there is greater benefit in chroma). For just RA, the difference was reportedly 0.5%, for just LD, the difference was 1.7%, and for just LD Classe E, the difference was reportedly 5.2%.

It was remarked that the use of varied QP scaling from frame to frame in the test conditions may affect the results.

It was remarked that the coding efficiency benefit relative to fixed rounding (and TPE) is an especially important thing to consider in evaluation of these reference memory compression schemes.

Decision: It was agreed that support for the fixed rounding case should be put into the HM software (not used in the reference configurations).

Decision: It was agreed that, when IBDI is turned on, the output of the decoding process is, in principle, extended bit depth video, and the PSNR should be calculated without rounding the output first, with PSNR calculated as PSNR = 10 * log10((255*2^(N-8))^2 / MSE).

Decision: The syntax should just indicate the bit depth of the video decoding process, not also an indication that the hypothetical input to the encoder was at some lower bit depth, as such an indicator provides no apparent benefit.

However, it would be good for the decoder to be configurable to reduce the output precision of the decoding process when writing its output.

Further study (e.g., in CE or AHG) was recommended.

JCTVC-D281 Cross-verification of Toshiba's proposal on reference frame memory compression for IBDI [Hirofumi Aoki, Keiichi Chono, Kenta Senzaki, Junji Tajime, Yuzo Senda]

Cross-verification of JCTVC-D152.

JCTVC-D025 Evaluation results on IBDI [M. Zhou (TI)]

This contribution advocated that IBDI deserves further study as it has significant impact on the implementation cost in terms of area and memory bandwidth. The document reports the IBDI coding efficiency with respect to the number of IBDI extension bits, and IBDI performance when the reference frame is stored in 8-bit instead of 12-bit. Evaluation results reportedly reveal that 2-bit IBDI extension is a good trade-off as it already captures 80 – 90% of potential IBDI gain. Tests also reportedly show that the IBDI gain almost vanishes when the reference frame storage bit depth is reduced from 12-bit to 8-bit.

The benefit for the Class E LD case, comparing IBDI (4 bits) to no IBDI and no TPE results in approximately 13.4% difference. Comparing IBDI (4 bits) to no IBDI but with TPE enabled results in approximately 11.4% difference.

For 4-bit IBDI, it was reported that the area and memory bandwidth increases by about 50%.

The contributor noted that 80%-90% of the IBDI benefit can be obtained with 2 bits of IBDI rather than 4. The contributor also indicated that, similarly, nearly all of the TPE benefit can be obtained with 2 bits of TPE.

Decision: It was agreed that our HE configuration should use 2 bits of IBDI rather than 4 bit (i.e., our reference HE configuration should support 10 bit decoding, but not 12 bit decoding.)

It was then discussed whether to change our LC configuration to use 2 bits of TPE rather than 4, but some reluctance was initially expressed about that due to a lack of submitted experiment data. This aspect was then further studied by the submitter of JCTVC-D025, and experiment results were submitted in JCTVC-D440.

JCTVC-D440 Evaluation results on TPE [M. Zhou (TI)] (BoG report registered Sunday 23rd after start of meeting, uploaded Sunday 23rd, fourth day of meeting)

After discussion of JCTVC-D025, the amount of TPE to be used in the LC configuration was then discussed further in response to late document registration JCTVC-D440.

This late information document confirmed the assertion that it was feasible to reduce TPE to 2 bits without significant impact on coding efficiency.

Decision: Agreed to reduce TPE to 2 bits.

It was noted that the TPE concept may not be necessary if a different transform design is used.

JCTVC-D023 Testing results of TI reference frame compression algorithm using TMuC-0.9 [M. Zhou, M. Budagavi (TI)]

This document reported testing results of the reference frame compression (RFC) algorithm proposed by Texas Instruments at the Geneva JCT-VC meeting. The algorithm was integrated into the TMuC-0.9 reference software and tested with the JCT-VC common testing conditions. For the High Efficiency (HE) configurations in which IBDI is on, the proposed algorithm reportedly provides 12 bits to 8 bits compression on the cost of an average BD BR increase of 0.2% for random access configurations and 1.6% for low-delay configurations, respectively. The average motion compensation memory bandwidth is reportedly reduced by 10.0% to 52.7%. For the low complexity (LC) configurations in which the IBDI is off, the proposed algorithm conducts 8 bits to 4 bits compression, the average BD BR increase is reportedly 2.3% for random access LC and 3.2% for low-delay LC, respectively. The memory bandwidth saving is reportedly 50% if the growing window is employed.

JCTVC-D157 Verification of TI's evaluation results of IBDI (JCTVC-D025) [T.Chujoh, T.Yamakage (Toshiba)]

Cross-verification of JCTVC-D025.

JCTVC-D296 Unbiased clipping for IBDI [Hirofumi Aoki, Keiichi Chono, Kenta Senzaki, Junji Tajime, Yuzo Senda]

In this contribution, it is proposed that the current biased clipping for IBDI, i.e., in the range of 0 to 1<<(8+bit_depth_minus8+bit_depth_increment) − 2bit_depth_ increment, is replaced with unbiased full-range clipping, in the range of 0 to 1<<(8+bit_depth _minus8+bit_depth _increment) − 1. The revised scaling for leveraging the extended range is also presented. Experimental results have reportedly shown that the performance difference is negligible.

The proponent suggested adding an offset of 8 when shifting up at the input side, and then just right shifting without adding an offset when converting the output to 8 bits is desired. It was remarked that it would be important for decoders to be aware of whether the offset was added at the input side or not.

It was remarked that another approach is to stretch the range from 0 to 255 by appending the 4 MSBs as LSBs of the left-shifted result, which was suggested to be a trick for approximating a rescaling stretch to the full range.

It was remarked that if the clipping uses the full range, then adding an offset and right shifting to convert to 8 bits can overflow the result.

It was noted that the 12 bit clipping range is presumably normative.

Decision: The clipping range modification was adopted.

The aspects relating to how to convert from 8 bits to 8+N bits at the input side and how to convert back to 8 bits at the output side were not adopted.

It was noted that we believe the inverse IBDI process is not normative (unless there is some inverse IBDI needed for reference picture storage, which is not the case at this time). From the perspective of the decoder, a decoder is simply receiving 8+N bit video and there is no need for the decoder to be aware that it may have originated previously from 8 bit input video.

JCTVC-D045 Rounding-error conscious memory compression method for IBDI [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda]

This contribution proposes a rounding-error conscious memory compression method for IBDI, in which bit depth reduction based on fixed rounding is introduced in prediction loop and an enhanced Sum of Squared Errors (SSE) computation is conducted by encoder. Simulation results reportedly show that in video coding systems based on in-loop fixed rounding, the enhanced SSE computation improves BD BR by 0.4% (Y), -0.2% (U), and 0.2% (V) for high efficiency random access setting, and 3.8% (Y), 0.9% (U), and 2.5% (V) for high efficiency low delay setting. Simulation results also reportedly demonstrate that IBDI with the rounding-error conscious memory compression attains BD BR improvements by 0.7% (Y), 4.3% (U), and 5.5%(V) for random access setting, and 1.4% (Y), 5.6% (U), and 6.4% (V) for low delay setting, without increasing reference picture memory bandwidth.

This contribution advocates the action noted above in the discussion of JCTVC-D152.

The contribution recommended to include in-loop fixed rounding as a reference point for comparisons in CE evaluation of IBDI and memory compression issues. This view was generally supported.

It was noted that chroma seems to be affected differently by the different rounding handling techniques.

JCTVC-D156 Verification of NEC's rounding-error conscious memory compression method for IBDI (JCTVC-D045) [T.Chujoh, T.Yamakage (Toshiba)]

Cross-verification of JCTVC-D045.

JCTVC-D035 Unified scaling with adaptive offset for reference frame compression with IBDI [D. Hoang (Zenverge)]

Internal Bit Depth Increase (IBDI) is a technique that increases the arithmetic precision of the prediction, transform, and loop filter in a design by increasing the sample bit depth at the input to the encoder. The main benefit is additional coding gain due to better intra-prediction and inter-prediction. The main drawback is that memory storage and bandwidth requirements are increased. Several reference frame compression (RFC) techniques have been proposed to reduce the memory storage and bandwidth penalty of IBDI. In this document, two RFC algorithms were proposed that were asserted to improve upon Toshiba's Dynamic Range Adaptive Scaling (DRAS), which was asserted to thus far be the best performing RFC proposal. Experimental results using HM version 0.9 reportedly show that for the low-delay high-efficiency configuration, these RFC algorithms reportedly retain about 90% of the coding efficiency gains of IBDI compared to 78% for DRAS. For the random-access high-efficiency configuration, these algorithms reportedly perform comparably to DRAS and retain over 90% of the coding efficiency gains of IBDI. The complexity of these RFC algorithms was reportedly similar to that of DRAS.

The modifications were:

- not including a fixed scaling option
- performing a different quantization of the minimum sample value
- a reconstruction offset is computed and applied

For the Class E LD case, variations of the proposal reportedly showed a BD BR loss of 2.0%-2.2% relative to IBDI.

For the Class E LD case, variations of the proposal reportedly showed a BD BR gain of 4.9%-8.3% relative to no IBDI *without* TPE.

Simulated memory bandwidth reduction was not reported, but was suggested to probably be similar to the prior Toshiba DRAS proposal. Computational complexity was also suggested to be similar to that of the

Further study was recommended (e.g., in a CE).

JCTVC-D086 Constrained intra prediction for reducing visual artifacts caused by lossy decoder-side memory compression [Keiichi Chono, Hirofumi Aoki, Xuan Jing, Viktor Wahadaniah, ChongSoon Lim, Sue Mon Thet Naing]

This contribution provides an investigation report on the effects of constrained intra prediction in the HEVC context, in particular, on its performance in reducing visual artifacts caused by encoder-decoder mismatch associated with lossy decoder-side memory compression. Using constrained intra prediction, experimental results reportedly show average BD BR losses of 2.1% (Y), 3.6% (U), 3.5% (V) for random access high efficiency setting, 1.8% (Y), 2.6% (U), 2.8% (V) for random access low complexity setting, 1.7% (Y), 3.7% (U), 3.6% (V) for low delay high efficiency setting, and 1.4% (Y), 2.9% (U), 3.1% (V) for low delay low complexity setting. This contribution also reportedly shows the benefit of constrained intra prediction in reducing visual artifacts when decoder-side memory compression is applied.

It is proposed that:

- Integrate the proposed constrained intra prediction into HM software and improve its implementations;
- Study the benefit of constrained intra prediction in reducing visual artifacts with different decoder-side memory compression schemes.

It was noted that reference picture memory compression can produce artifacts when constrained intra prediction is not used.

A participant brought up the topic of what to do when some samples are available and others are not.

It was noted that we appear to have already decided to put the constrained intra prediction flag into the PPS, as a carry-over from AVC.

The contributor additionally noted a mismatch between the text and software for the encoder (not the decoder). The current software is assuming that the below-left samples are not available when the prediction block size is 4x4 or 8x8. This looks like a software bug.

Decision: The software should be fixed to account for the true availability status. (NEC volunteers: the fix is just removing two lines.)

Constrained intra prediction (in some form) is advocated to be added in JCTVC-D094 and JCTVC-D386 as well as JCTVC-D086.

Decision: Adopted. NEC volunteers the software.

Further study is also encouraged.

JCTVC-D280 Performance report of DPCM-based memory compression on TMuC 0.9 [Hirofumi Aoki, Keiichi Chono, Kenta Senzaki, Junji Tajime, Yuzo Senda]

This contribution presents a performance report of DPCM-based reference frame memory compression scheme proposed in JCTVC-B057, JCTVC-C094 and JCTVC-C095 on TMuC 0.9. For 12-bit to 7.5-bit compression in high efficiency configurations where IBDI is enabled, coding losses of the proposed scheme measured by BD BRs are reportedly 1.2% with fixed quantization and 0.7% with adaptive quantization introduced in JCTVC-C095. It should be noted that these are less than those of fixed rounding presented in JCTVC-D045. As for memory access bandwidth, the average reduction was reported to be 47.8%. For 8-bit to 5.5-bit compression in low complexity configurations where IBDI is disabled, the average coding losses are reported to be 8.2% with fixed quantization and 4.7% with adaptive quantization, and the average memory access bandwidth reduction is reported as 55.2%. It should was asserted that the scheme has potential for more gain by encoder optimizations, since the results shown here are obtained with the same quantization matrix set both for luma and chroma components, and for all pictures of all sequences. It was proposed that the DPCM-based memory compression scheme be further studied in the context of Core Experiments.

The proposal produces a fixed memory compression rate.

Further study was encouraged (e.g., in a CE).

18 Plenary Discussions and BoG Reports

Entropy coding dependency discussion

A discussion of inter-frame dependency for parsing was held on Monday 24th at 2 p.m. A chair raised the following question for discussion: If a dependency of entropy decoding from a previous-frame slice were allowed, could it potentially improve the compression efficiency? If it is allowed in one case of motion vector prediction, why not in other cases? Comments made in response included the following:

- It would only be worthwhile if it provides sufficient gain in terms of compression performance

- Would need to be switchable in order to operate in lossy environments or for random access
- For several slices within one frame, no dependency should exist for the purpose of parallelism

Currently this is purely hypothetical topic, but several experts think it could be interesting to perform a study of cases in which this question arises, either in an AHG or CE.

JCTVC-D445 BoG Draft of proposed new CE10 on Core Transforms [Pankaj Topiwala, Robert Cohen, Madhukar Budagavi, Rajan Joshi] (BoG draft of proposed new CE registered Monday 24th after start of meeting, uploaded Monday 24th, fifth day of meeting)

This BoG report presented a draft CE on transform design. Remarks made during its discussion included the following:

- QP range should be as wide as possible (down to 0/1 if entropy coder allows)
- Test the dynamic range at different points (input/output of quantization/transform)
- Regarding "Implementation in software and hardware" – how will the latter be done? Some proponents may not be familiar with the appropriate hardware development/simulation tools – needs further discussion. Also, the period until the next meeting is rather short.

JCTVC-D443 BoG report on Intra Prediction Improvements [Ali Tabatabai] (BoG report registered Monday 24th after start of meeting, uploaded Monday 24th, fifth day of meeting)

This BoG report concerned intra prediction, and the following comments were made during its discussion:

- Plan to work on possible improvements based on feedback of meeting within next 2-3 weeks
- Start work on collaboration bringing several tools together afterwards
- Only focus on intra prediction elements (no combinations with elements that would fit in other CEs)
- Analysis of complexity: Provide a template to fill number of operations at block level, pixel level, recursions etc.
- Separate analysis of luma and chroma
- Sequence of reporting concatenation of improvements should be A-bugfixes B-improved signalization C-new modes D- complexity reductions
- In case of combinations (e.g. prediction and transforms) results should be reported such that also the standalone performance of prediction can be judged
- Need to clarify which version of software to use for CEs

JCTVC-D441 BoG report of CE9: Motion Vector Coding [T. K. Tan (NTT DOCOMO), W.-J. Han (Samsung), B. Bross (Fraunhofer HHI), J. Jung (Orange Labs), K. McCann (Samsung), Y. Suzuki (NTT DOCOMO), G. Clare (Orange Labs), H. Schwarz (Fraunhofer HHI), A. Fujibayashi (NTT DOCOMO)] (BoG report registered Sunday 23rd after start of meeting, uploaded Monday 24th, fifth day of meeting)

This BoG recommended to adopt PU-level merging with AMVP skip on CU-level (3.1.t) with the following Partial Merging restrictions when a CU has a size greater than the minimum CU size (currently 8x8) is split into 2NxN or Nx2N PUs (JCTVC-D233):

- The first PU is inferred to be merged
- The second PU signaling follows 3.1.t (allows either merge or MV coding)

Decision: Adopted.

Due to the fact that 3.1.e and 3.1.t are very similar, it was recommended to create a CE on the MV derivation process. The difference between 3.1.e and 3.1.t is that in 3.1.t, skip is enabled with derivation of the MV from MV Coding, in 3.1.e, there is no skip mode but there is a merge with no residual. The adopted design, and the reference of the CE should be:

- 3.1.t (Direct off included, which was agreed)
- Partial Merge (encoder/decoder restrictions agreed as described above)
- Disable NxN PU split (agreed)
- Temporal Center Predictor (agreed)

Decision: Agreed.

Post-meeting clarification: The software also includes several high-level flags that are not (yet) documented in the draft text. These include "motion_vector_merge_disabled_flag". Our understanding is that this flag (and the associated ability to disable merging) is in the design and should be added to the draft text. Other such flags found in the software include adaptive_loop_filter_disabled_flag, delta_qp_disabled_flag, low_delay_coding_disabled_flag, and motion_vector_competition_disabled_flag. It seems likely that adaptive_loop_filter_disabled_flag, and possibly delta_qp_disabled_flag should also be kept and documented, and possibly the other two as well.

JCTVC-D457 BoG report on deblocking filter - subjective viewing and decoder run-time [Rickard Sjoberg (Ericsson), David Flynn (BBC)] (BoG report registered Thursday 27th after start of meeting, uploaded Thursday 27th, near the end of the meeting)

This report is about further testing the subjective quality of proposals JCTVC-D377 (Ericsson), JCTVC-D214 (Panasonic) and JCTVC-D263 (Sony). An expert viewing test coordinated by V. Baroncini was performed, which did not unveil noticeable differences. Also, decoder run-times of these deblocking filter proposals and proposals JCTVC-D163 (MediaTek) and JCTVC-D334 (SKKU) were investigated by a non-proponent (BBC).

JCTVC-D458 BoG report on Screen Content Coding (SCC) [O. C. Au(HKUST), J. Xu(Microsoft), H. Yu(Huawei)] (BoG report registered Thursday 27th after start of meeting, uploaded Thursday 27th, near the end of the meeting)

This contribution provides a summary of the Break Out group meeting on Screen Content Coding (SCC) held at 2pm-4pm on Jan 25, 2011. A draft call for sequences “class F” wa also included in the zip archive.

This activity ultimately resulted in issuing the output document JCTVC-D501.

19 Project planning

19.1 WD drafting and software, and relationship to contributions

The current WD is still much in a draft status (e.g. no description of LCEC at all). In future meetings, 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 CEs).

19.2 General issues for CEs

Because a draft design and HEVC test model (referred to as the HM) have now been established, group coordinated experiments are now referred to as "core experiments" rather than "tool experiments".

A preliminary CE description is to be approved at the meeting at which the CE plan is established.

It is possible to define sub-experiments within particular CEs, for example designated as CEX.a, CEX.b, etc., for a CEX, 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 HM 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 experiments were described in the output document JCTVC-D600.

A deadline of two weeks after the meeting was established for organizations to express their interest in participating in a CE to the CE coordinators and for finalization of the CE descriptions by the CE coordinator with the assistance and consensus of the CE participants.

Final CEs should clearly describe specific tests to be performed, not describe vague activities. Activities of a less specific nature are delegated to Ad Hoc Groups rather than designated as CEs.

Experiment descriptions should be written in a way such that it is understood as a JCT-VC output document (written from an objective "third party perspective", not a company proponent perspective – e.g. referring to methods as "improved", "optimized" etc.). The experiment descriptions should generally not express opinions or suggest conclusions – rather, they should just describe what technology will be tested, how it will be tested, who will participate, etc. Responsibilities for contributions to CE work should identify individuals in addition to company names.

CE descriptions should not contain 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 referenced documents that are also available in the JCT-VC document archive.

Those who proposed technology in the respective context (by this or the previous meeting) can propose a CE or CE sub-experiment. Harmonizations of multiple such proposals and minor refinements of proposed technology may also be considered. Other subjects would not be designated as CEs.

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.

It is strongly recommended to plan resources carefully and not waste time on technology that may have little or no apparent benefit – it is also within the responsibility of the CE coordinator to take care of this.

CE participants are obligated to submit a report of the results of their experiment testing and any further analysis of the subject matter. Each participant is required to submit a report – measures will be taken if this principle is violated (especially if repeatedly violated) without good reason.

A summary report written by the coordinator (with the assistance of the participants) is also expected to be provided to the subsequent meeting. The review of the status of the work on the CE at the meeting is expected to rely heavily on the summary report, so it is important for that report to be well-prepared, thorough, and objective.

Non-final CE plan documents were reviewed and given tentative approval during the meeting (in some cases with guidance expressed to suggest modifications to be made in a subsequent revision).

The CE description for each planned CE is described in an associated output document JCTVC-D6xx for CExx, where "xx" is the CE number (xx = 01, 02, etc.). Final CE plans are recorded as revisions of these documents.

It must be understood that the JCT-VC is not obliged to consider the test methodology or outcome of a CE as being adequate. Good results from a CE do not impose an obligation on the group to accept the result (e.g., if the expert judgment of the group is that further data is needed or that the test methodology was flawed).

19.3 Common Conditions for HEVC Coding Experiments

Preferred Common Conditions for experiment testing that are intended to be appropriate for both CEs and other experiments were selected by the group and described in output document JCTVC-D600.

19.4 Software development

The software coordinator had already started integrating bug fixes on top of HM 1.0 software. As there are substantial changes relative to TMuC 0.9, it was recommended that participants start studying and implementing their technology based on HM 1.0 immediately, considering the short time period until the 5th meeting. The software version HM 2.0, which is intended to become the basis of CE experimentation, will be available 2 weeks after the meeting. HM 2.1 (including adoptions which appear less relevant in CEs) will follow later.

A version of the software should be available within 2 weeks that should be suitable for CEs.

20 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 will be the main JCT-VC reflector (jct-vc@lists.rwth-aachen.de).

Title and Email Reflector	Chairs	Mtg
JCT-VC project management (jct-vc@lists.rwth-aachen.de) • Coordinate overall JCT-VC interim efforts • Report on project status to JCT-VC reflector • Provide report to next meeting on project coordination status	G. J. Sullivan, J.-R. Ohm (co-chairs)	N
HEVC Draft and Test Model editing (jct-vc@lists.rwth-aachen.de) • Produce and finalize JCTVC-D502 HEVC Test Model 2 (HM 2) Encoder Description • Produce and finalize JCTVC-D503 HEVC text specification Working Draft 2 • Gather and address comments for refinement of these documents • Coordinate with the Software development and HM software technical evaluation AhG to address issues relating to mismatches between software and text	T. Wiegand, K. McCann (co-chairs), B. Bross, W.-J. Han, J.-R. Ohm, J. Ridge, S. Sekiguchi, G. J. Sullivan (vice chairs)	N

Software development and HM software technical evaluation (jct-vc@lists.rwth-aachen.de) • Coordinate development of the HM software and its distribution to JCTVC members • Produce documentation of software usage for distribution with the software • Prepare and deliver HM 2.0 software version and the reference configuration encodings according to JCTVC-D600 based on common conditions suitable for use in most core experiments (expected within two weeks after the meeting). • Prepare and deliver HM 2.1 software (and possibly additional "dot" version software releases) that includes additional items not integrated into the 2.0 version (expected two weeks prior to the next meeting). • Coordinate with HEVC Draft and Test Model editing AhG to identify any mismatches between software and text	F. Bossen (chair), D. Flynn, K. Sühring (vice chairs)	N
Slice support development and characterization (jct-vc@lists.rwth-aachen.de) • Assist the software development and HM software technical evaluation ad hoc group with integration of basic slice (independently-decodable sequences of largest coding units in raster-scan order) and "entropy slice" support into the HM 2.1 software. • Identify issues relating to the draft text description of slice functionality • Consider spatial granularity of slice boundaries • Study technical proposals relating to slice structured coding • Study the coding efficiency and loss resilience impact of slice-structured coding • Identify and discuss additional issues relating to slice-structured coding	R. Sjöberg (chair), Y. Chen, M. Horowitz, K. Kazui, A. Segall (vice chairs)	N

Spatial transforms (jct-vc@lists.rwth-aachen.de) • Study the ("core" and "alternative") transforms in the HM design, including compression performance, computational complexity, dynamic range, clipping, storage requirements, etc. • Perform analysis of block transform design and architecture, including software and hardware considerations. • Discuss transform-related Core Experiments, and identify potential synergies or incompatibilities related to the tools being tested in the CEs. • Report the results and conclusions of these discussions and experiments to the JCT-VC.	P. Topiwala (chair), M. Budagavi, R. Cohen, R. Joshi (vice chairs)	N
In-loop and post-processing filtering (jct-vc@lists.rwth-aachen.de) • Study enhancement schemes of in-loop filtering, including de-blocking/de-banding/de-noising filters, and adaptive Wiener-based filters including variants with various inputs, and combination of filters • Study trade-offs and characteristics of filter designs including complexity and subjective and objective performance • Discuss relationships and evaluation procedures for the filtering techniques • Identify possibilities for harmonization of enhanced in-loop filtering technologies • Study the relationship between in-loop and post-processing filtering	T. Yamakage (chair), K. Chono, Y. J. Chiu, I. S. Chong, M. Narroschke (vice chairs)	N
Coding block structures (jct-vc@lists.rwth-aachen.de) • Study techniques of HM relating to coding block structure • Characterize the trade-offs involved in coding block structure issues, including complexity, redundancy and compression performance aspects • Identify opportunities for harmonization and simplification of coding block structure	K. Panusopone (chair), W.-J. Han, T. K. Tan, T. Wiegand (vice chairs)	N

Reference pictures memory compression (jct-vc@lists.rwth-aachen.de) • Study motion compensation memory access bandwidth of HM design • Study clipping and rounding schemes of extended bit depth values for reference picture storage • Study reference picture memory compression schemes in HM design • Study data format alignment between reference picture memory compression and display processing • Study the visual quality impact of reference picture memory compression • Report on conclusions reached	K. Chono (chair), T. Chujoh, C. S. Lim, A. Tabatabai, M. Zhou (vice chairs)	N
Entropy coding (jct-vc@lists.rwth-aachen.de) • Study the entropy coding complexity and compression characteristics of CABAC, LCEC, PIPE/V2V, and other entropy coding designs • Consider the potential for harmonization of HE and LC entropy coding designs • Characterize throughput, memory, silicon area, power requirements, etc. • Study parallel context processing, syntax-element partitioning, and other parallelism approaches for entropy coding • Consider IPCM coding and effect of the maximum number of potential coded bits for coded regions • Study and develop approaches for hardware and software evaluation of entropy coding methods • Identify and discuss additional issues on entropy coding	M. Budagavi (chair), G. Martin-Cocher, A. Segall (vice chairs)	N

Quantization (jct-vc@lists.rwth-aachen.de) • Study quantization issues in HM design, including sub-LCU dQP, Quantization matrix, etc. • Study trade offs and characteristics of quantization design, including coding efficiency and complexity • Study the impact on subjective quality improvement and coordinate preparations for subjective viewing test at Geneva, if necessary • Identify issues relating to tools tested only with RDOQ enabled. • Study new quantization schemes such as adaptive quantization level (AQL) with RDOQ on and RDOQ off • Study adequacy of current mapping of QP to quantizer step-size for rate control at different coding levels (LCU, slice, frame, etc.)	M. Budagavi (chair), K. Sato, G. Martin-Cocher (vice-chairs)	N
Video test material selection (jct-vc@lists.rwth-aachen.de) • Identify, collect, and make available a variety of video sequence test material • Study the coding performance and characteristics of test materials • Identify and recommend appropriate test materials and corresponding test conditions for use in HEVC development	T. Suzuki (chair)	N

Complexity assessment (jct-vc@lists.rwth-aachen.de) • Summarize and evaluate the various complexity assessment methods proposed in CEs and AHGs groups with regards to : ▪ computational complexity, ▪ parallelism, ▪ memory bandwidth, ▪ memory capacity, ▪ dynamic range requirements, ▪ any other aspects of complexity identified as being of interest. • Develop and propose a set of general measurement metrics that can be used across the various CEs and AHGs. • Develop and propose a metric for measuring the parallelizability of the proposed parallel algorithms, especially with regards to the parallelization at the slice level. • Identify criteria to determine the hardware implementability of the key hardware modules. • Identify bottlenecks in the current design with regard to implementation complexity.	D. Alfonso (chair), J. Ridge, X. Wen (vice chairs)	N
Motion compensation interpolation (jct-vc@lists.rwth-aachen.de) • Study the coding efficiency and complexity characteristics of proposed interpolation filtering methods • Draft proposed core experiments relating to motion compensation interpolation • Identify and discuss additional issues relating to motion compensation filtering	K. Ugur (chair), E. Alshina, P. Chen, T. Chujoh (vice chairs)	N

Screen content coding (jct-vc@lists.rwth-aachen.de) • To coordinate the submission, evaluation and selection of "screen content" video test material • To study characteristics of screen content video • To study evaluation methods, test conditions. and metrics for coding tools designed for screen content video • Study technology that may be particularly well suited to the coding of screen content video • Study use cases in which screen content video is prevalent and identify potential associated technical implications	O. Au (chair), J. Xu, H. Yu (vice chairs)	N
Parsing robustness (jct-vc@lists.rwth-aachen.de) • Study the degree of loss robustness of the parsing process in the HM design and identify deficiencies • Investigate solutions to improve parsing robustness • Investigate the trade-off between coding efficiency and loss robustness • Discuss related Core Experiments, and identify potential synergies or incompatibilities related to the tools being tested in the CEs	J. Xu (chair), M. Coban, Y. W. Huang, J. Jung, P. Onno, (vice chairs)	N
High-level syntax (jct-vc@lists.rwth-aachen.de) • Study NAL unit header, sequence parameter set, picture parameter set, and slice header syntax designs • Study reuse of AVC SEI messages • Study possible improvements to the reference picture list construction process • Study possible simplifications and improvements to reference picture marking process (e.g., the need of the processes for generating and handling of "non-existing" pictures) • Study the hypothetical reference decoder behaviour • Assist in software development and text drafting for the high-level syntax in the HEVC design	Y. K. Wang (chair), J. Boyce, Y. Chen, K. Kazui, T. Schierl, R. Sjöberg, T. K. Tan (vice chairs)	N

Decoder-side motion vector derivation (jct-vc@lists.rwth-aachen.de) • Study the techniques of decoder side motion vector derivation to improve video compression • Investigate inference processing techniques such as optical-flow at the decoder side • Study the performance/complexity tradeoffs of uni/bi-predictional-based methods to derive motion vector information at decoder side • Study complexity/performance of parallel processing for decoder-side inference techniques to improve video compression	Y.-J. Chiu (chair), E. Alshina, H. Yu (vice chairs)	N
Scalable coding investigation (jct-vc@lists.rwth-aachen.de) • Investigate hooks that would be needed for support of bitstream scalability in HEVC syntax • Study the applicability and effectiveness (e.g., relative to simulcast and single-layer coding) of scalability tools in AVC for the HEVC context • Study potential experimental conditions for evaluation of scalability features	J. Boyce (chair), J. Kang, W. Wan, Y.-K. Wang (vice chairs)	N

21 Output documents

The following documents were agreed to be produced as outputs of the meeting. Names recorded below indicate those responsible for document production.

Note: JCTVC-C404 will remain as our approved software guidelines.

JCTVC-D404 HEVC Reference Software Manual [F. Bossen, D. Flynn, K. Suehring (AHG chairs)] (missing prior, uploaded Thursday 20th, first day of the meeting)

Note: JCTVC-D404 (as updated) was approved as the software manual.

JCTVC-D500 Meeting Report of 4th JCTVC Meeting [G. J. Sullivan, J.-R. Ohm]

JCTVC-D501 Request for Video Test Material for "Screen Content" Coding Experiments [G. J. Sullivan, J.-R. Ohm, O. C. Au] (WG 11 N 11867)

JCTVC-D502 High Efficiency Video Coding (HEVC) Test Model 2 (HM 2) Encoder Description [K. McCann (primary), B. Bross, S. Sekiguchi] (WG 11 N 11818)

JCTVC-D503 High Efficiency Video Coding (HEVC) text specification Working Draft 2 [T. Wiegand (primary), W.-J. Han, G. J. Sullivan, J.-R. Ohm] (WG 11 N 11819)

JCTVC-D600 Common HM test conditions and software reference configurations [F. Bossen]

Note: Some aspects included were:

- Test sequences
- JCTVC-D356 impact (e.g., number of reference pictures)
- QP settings (e.g. for LD)

JCTVC-D601 Core Experiment 1: Decoder-side Motion Vector Derivation [Y.-J. Chiu (primary), Y.-W. Huang, W.-H. Peng, S. Sekiguchi, H. Yu]

JCTVC-D602 Core Experiment 2: Flexible Motion Partitioning [X. Zheng (primary), P. Bordes, P. Chen, I.-K. Kim]

JCTVC-D603 Core Experiment 3: Interpolation for MC (Luma) [E. Alshina, T. Chujoh]

JCTVC-D604 Core Experiment 4: Slice Boundary Processing and Slice Granularity [Y. W. Huang, I-K. Kim]

JCTVC-D605 Core Experiment 5: Low Complexity Entropy Coding Improvement [X. Wang]

JCTVC-D606 Core Experiment 6: Intra prediction improvements [A. Tabatabai (primary), K. Chono, M. Coban, M. Mrak, A. Tanizawa, H. Yu]

JCTVC-D607 Core Experiment 7: Alternative transforms [R. Cohen (primary), F. Fernandes, R. Joshi, C. Yeo]

JCTVC-D608 Core Experiment 8: Non-deblocking loop filtering [T. Yamakage (primary), I. S. Chong, M. Narroschke]

JCTVC-D609 Core Experiment 9: MV coding and Skip/Merge operation [J. Jung (primary), B. Bross, P. Chen, W.-J. Han]

JCTVC-D610 Core Experiment 10: Core Transforms [P. Topiwala (primary), M. Budagavi, A. Fuldseth, R. Joshi, I-K. Kim]

JCTVC-D611 Core Experiment 11: Coefficient Scanning and Coding [V. Sze (primary), J. Chen, M. Coban, T. Nguyen, K. Panusopone]

JCTVC-D612 Core Experiment 12: Deblocking Filter [A. Norkin (primary), B. Jeon, M. Narroschke]

JCTVC-D613 Core Experiment 13: Sample-Adaptive Offset [Y. W. Huang]

JCTVC-D614 Core Experiment 14: Intra Mode Coding [S. Lei, M. Karczewicz]

22 Future meeting plans, expressions of thanks, and closing of the meeting

Future meeting plans were established according to the following guidelines:

- Meeting under ITU-T SG 16 auspices when it meets (starting meetings on the Tuesday or Wednesday of the first week and closing it on the Tuesday or Wednesday of the second week of such meeting), and
- Otherwise meeting under ISO/IEC JTC 1/SC 29/WG 11 auspices when it meets (starting meetings on the Wednesday or Thursday prior to such meetings and closing it on the last day of the WG 11 meeting).

Some specific future meeting plans were established as follows:

- 16-23 March 2011 in Geneva, Switzerland under the auspices of ITU-T Q6/16.
- 14-22 July 2011 under WG 11 auspices in Torino, IT.
- 22-30 November 2011 under ITU-T auspices in Geneva, CH.
- 1-10 February 2012 under WG 11 auspices in San José, USA.

The JCT-VC thanked Prof. Byeungwoo Jeon, Mr. Hyunmyong Cho, Mr. Jae Hwan Kim, Mr. Jungyoup Yang, and Mr. HeeChul Yang of Sung Kyun Kwan University for assistance with the video viewing experiments performed during the 4th meeting of the JCT-VC.

The local hosts of the meeting and the WG11 parent body under whose auspices the meeting was held were thanked for the arrangements provided for the meeting. The local hosts included the Korean Agency for Technology and Standards (KATS) and Korean Standards Association (KSA). The Daegu Metropolitan City and Samsung Electronics Co., Ltd. provided their support and hosting of a social event during the meeting.

The JCT-VC meeting was closed at approximately 1:55 p.m. on Friday 28 January 2011.

Annex A to JCT-VC report:
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JCTVC-D001	m19151	2011-01-15 21:57:47	2011-01-20 22:31:24	2011-01-20 22:31:24	JCT-VC AHG report: Project management	J.-R. Ohm, G. J. Sullivan (AHG Chairs)
JCTVC-D002	m19187	2011-01-16 15:59:34	2011-01-19 13:31:26	2011-01-19 13:31:26	JCT-VC AHG report: HEVC Draft and Test Model editing	K. McCann, T. Wiegand (co-chairs), B. Bross, W.-J. Han, J.-R. Ohm, J. Ridge, S. Sekiguchi, G. J. Sullivan (vice chairs)
JCTVC-D003	m19119	2011-01-15 18:41:48	2011-01-20 08:38:06	2011-01-20 08:38:06	JCT-VC AHG report: Software development and HM software technical evaluation	F. Bossen, D. Flynn, K. Sühring (AHG Chairs)
JCTVC-D004	m19161	2011-01-16 00:11:46	2011-01-19 05:05:50	2011-01-19 05:05:50	JCT-VC AHG report: Slice support development and characterization	R. Sjöberg, K. Kazui, Y. Chen
JCTVC-D005	m19189	2011-01-16 22:54:44	2011-01-16 23:04:27	2011-01-20 07:30:02	JCT-VC AHG report: Spatial Transforms	P. Topiwala, R. Cohen, M. Budagavi, R. Joshi
JCTVC-D006	m19018	2011-01-15 02:52:37	2011-01-19 09:32:20	2011-01-20 06:52:26	JCT-VC AHG report: In-loop and post-processing filtering	T. Yamakage, K. Chono, Y. J. Chiu, I. S. Chong, M. Narroschke (AHG Chairs)
JCTVC-D007	m19146	2011-01-15 21:38:09	2011-01-18 06:44:25	2011-01-18 06:44:25	JCT-VC AHG report: Coding block structures	K. Panusopone, W.-J. Han, T. K. Tan, T. Wiegand (AHG Chairs)
JCTVC-D008	m19227	2011-01-17 10:14:55	2011-01-18 11:50:34	2011-01-18 11:50:34	JCT-VC AHG report: Reference pictures memory compression	K. Chono, T. Chujoh, C. S. Lim, A. Tabatabai, M. Zhou
JCTVC-D009	m19030	2011-01-15 04:31:09	2011-01-18 02:27:19	2011-01-20 01:11:45	JCT-VC AHG report: Entropy coding	M. Budagavi, G. Martin-Cocher, A. Segall (AHG Chairs)
JCTVC-D010	m19363	2011-01-18 08:27:21	2011-01-20 10:59:23	2011-01-20 10:59:23	JCT-VC AHG report: Entropy slices	A. Segall, V. Sze, Y.-W. Huang
JCTVC-D011	m19052	2011-01-15 09:15:22	2011-01-18 09:19:36	2011-01-20 01:08:15	JCT-VC AHG report: Video test material selection	T. Suzuki (AHG chair)
JCTVC-D012	m19167	2011-01-16 00:39:06	2011-01-16 00:41:57	2011-01-16 00:44:17	JCT-VC AHG report: Complexity assessment	D. Alfonso (chair), J. Ridge, X. Wen (vice-chairs)
JCTVC-D013	m19117	2011-01-15 18:12:00	2011-01-20 01:13:09	2011-01-20 01:13:09	JCT-VC AHG report: Motion compensation interpolation	K. Ugur, E. Alshina, P. Chen, T. Chujoh (AHG Chairs)

JCTVC-D021	m18758	2010-12-30 01:11:17	2010-12-30 01:25:28	2010-12-30 01:25:28	USNB Contribution: Response to WG11 resolution 10.1.3 of the 94th meeting	A. G. Tescher for USNB of WG11
JCTVC-D022	m18759	2010-12-30 01:13:38	2010-12-30 01:26:43	2010-12-30 01:26:43	USNB Contribution: Response to WG11 resolution 10.1.4 of the 94th meeting	A. G. Tescher for USNB of WG11
JCTVC-D023	m18762	2011-01-04 20:49:12	2011-01-15 02:47:47	2011-01-15 02:47:47	Testing results of TI reference frame compression algorithm using TMuC-0.9	M. Zhou, M. Budagavi (TI)
JCTVC-D024	m18763	2011-01-04 22:34:30	2011-01-15 02:42:17	2011-01-15 02:42:17	Compact representation of quantization matrices for HEVC	M. Zhou, V. Sze (TI)
JCTVC-D025	m18764	2011-01-04 23:49:15	2011-01-15 02:34:35	2011-01-17 03:46:45	Evaluation results on IBDI	M. Zhou (TI)
JCTVC-D026	m18772	2011-01-09 07:59:31	2011-01-15 03:19:13	2011-01-20 11:48:45	CE6.a.5: Santa Clara University and Hisilicon Report on Block Based Intra Prediction	Guichun Li, Lingzhi Liu, Nam Ling, Jianhua Zheng, Philipp Zhang
JCTVC-D027	m18766	2011-01-06 01:18:42	2011-01-15 02:44:57	2011-01-17 00:19:16	List of items requiring clarification/action in HM1	A. Osamoto, M. Zhou, V. Sze (TI)
JCTVC-D028	m18769	2011-01-06 12:58:43	2011-01-06 13:07:11	2011-01-06 13:07:11	JNB comments on WG11 Resolution 10.1.3: Coding of screen content	JNB of WG11
JCTVC-D029	m18771	2011-01-07 04:48:01	2011-01-14 02:41:27	2011-01-15 10:29:09	Withdrawn - Duplicate registration	
JCTVC-D030	m18773	2011-01-10 01:57:54	2011-01-16 11:23:41	2011-01-16 11:23:41	CE7: Cross-verification of Samsung's (JCTVC-D357) Fast Rotational Transform	R. Cohen, A. Vetro, H. Sun (Mitsubishi)
JCTVC-D031	m18774	2011-01-10 20:44:30	2011-01-14 12:03:41	2011-01-21 01:56:24	CE7: Cross-check for Samsung's Proposal on Jointly Optimal Intra Prediction and Adaptive Primary Transform by BBC	Ying Weng (BBC)
JCTVC-D032	m18775	2011-01-10 22:22:36	2011-01-15 22:35:09	2011-01-21 01:26:54	CE 7: Cross-Check for Toshiba's proposal on 1-D Directional Unified Transform by Samsung	A. Saxena, F. C. Fernandes (Samsung)
JCTVC-D033	m18776	2011-01-10 22:25:19	2011-01-16 05:27:17	2011-01-22 01:27:44	CE7: Mode-dependent DCT/DST for intra prediction in video coding	Ankur Saxena, , Felix C. Fernandes
JCTVC-D034	m18781	2011-01-12 13:54:40	2011-01-14 18:54:58	2011-01-20 00:40:43	Specification of cropped Super Hi-Vision test sequences	A. Ichigaya, K. Iguchi, S. Sakaida, Y. Shishikui,
JCTVC-D035	m18782	2011-01-12 22:47:34	2011-01-16 06:01:36	2011-01-21 04:34:49	Unified scaling with adaptive offset for reference frame compression with IBDI	D. Hoang (Zenverge)
JCTVC-D036	m18783	2011-01-12 22:59:09	2011-01-15 23:33:45	2011-01-25 04:52:58	Matrix multiplication specification for HEVC transforms	M. Sadafale, M. Budagavi (TI)
JCTVC-D037	m18784	2011-01-12 23:01:02	2011-01-15 11:27:31	2011-01-19 19:03:04	DCT+Hadamard large transform	M. Budagavi, A. Gupte (TI)
JCTVC-D038	m18785	2011-01-12 23:05:44	2011-01-15 23:35:35	2011-01-19 16:14:18	Delta QP signaling at sub-LCU level	M. Budagavi, M. Zhou (TI)

JCTVC-D039	m18786	2011-01-12 23:07:16	2011-01-16 03:27:52	2011-01-25 04:45:29	ALF decode complexity analysis and reduction	M. Budagavi, V. Sze, M. Zhou (TI)
JCTVC-D040	m18787	2011-01-12 23:54:02	2011-01-16 02:57:39	2011-01-24 10:53:07	PSNR computation on R'G'B' color system	D. Hoang (Zenverge)
JCTVC-D041	m18788	2011-01-13 00:05:37	2011-01-14 19:23:14	2011-01-21 04:38:34	Finer scaling of quantization parameter	D. Hoang (Zenverge)
JCTVC-D042	m18789	2011-01-13 01:51:40	2011-01-16 12:00:27	2011-01-21 01:02:02	CE7: Alternative Transforms - Summary Report	R. Cohen, C. Yeo, R. Joshi
JCTVC-D043	m18790	2011-01-13 02:06:32	2011-01-15 16:38:27	2011-01-19 18:42:41	CE8: Conditional joint deblocking-debanding filter	K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda,
JCTVC-D044	m18791	2011-01-13 02:13:53	2011-01-15 07:15:24	2011-01-21 08:42:15	Pulse code modulation mode for HEVC	K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda,
JCTVC-D045	m18792	2011-01-13 02:17:09	2011-01-15 07:15:53	2011-01-21 13:19:02	Rounding-error conscious memory compression method for IBDI	K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda
JCTVC-D046	m18793	2011-01-13 02:24:03	2011-01-15 02:07:03	2011-01-20 15:49:31	CE7: Mode-Dependent Transforms for Block-based Intra Coding from Institute for Infocomm Research	C. Yeo, Y. H. Tan, Z. Li, S. Rahardja (I2R)
JCTVC-D047	m18794	2011-01-13 02:27:00	2011-01-15 02:08:03	2011-01-15 02:08:03	CE7: Cross-check of Huawei's proposal by Institute for Infocomm Research	C. Yeo, Y. H. Tan, Z. Li (I2R)
JCTVC-D048	m18795	2011-01-13 02:31:02	2011-01-15 02:10:34	2011-01-21 11:23:18	Low-Complexity 4-point Integer Discrete Sine Transform	C. Yeo, Y. H. Tan, Z. Li (I2R)
JCTVC-D049	m18796	2011-01-13 02:32:22	2011-01-15 02:11:26	2011-01-21 11:21:46	Mode-Dependent Coefficient Scanning for Intra Prediction Residual Coding	C. Yeo, Y. H. Tan, Z. Li (I2R)
JCTVC-D050	m18797	2011-01-13 04:00:52	2011-01-15 07:16:52	2011-01-17 02:32:46	CE10: Cross-check report from Institute for Infocomm Research	Y. H. Tan, C. Yeo, Z. Li (I2R)
JCTVC-D051	m18798	2011-01-13 04:05:39	2011-01-15 07:17:41	2011-01-17 02:31:01	Merge/Skip/Direct Simplification	Y. H. Tan, C. Yeo, Z. Li (I2R)
JCTVC-D052	m18799	2011-01-13 05:39:20	2011-01-15 12:24:16	2011-01-15 12:24:16	Updated evaluation result of proposed syntax and semantics for very low delay coding	Kimihiko Kazui, Junpei Koyama, Akira Nakagawa (Fujitsu)
JCTVC-D053	m18800	2011-01-13 05:40:27	2011-01-15 12:24:57	2011-01-15 12:24:57	Draft description of proposed syntax and semantics for very low delay coding	Kimihiko Kazui, Junpei Koyama, Akira Nakagawa (Fujitsu),
JCTVC-D054	m18801	2011-01-13 05:41:47	2011-01-15 12:25:34	2011-01-25 00:50:32	Benefit of the new syntax and semantics for very low delay coding in HEVC	Kimihiko Kazui, Junpei Koyama, Akira Nakagawa (Fujitsu),
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JCTVC-D056	m18803	2011-01-13 11:21:40	2011-01-15 22:00:46	2011-01-16 17:42:48	CE3: Luma Interpolation using MOMS	H. Lakshman, H. Schwarz, D. Marpe, T. Wiegand (Fraunhofer HHI)

JCTVC-D057	m18804	2011-01-13 11:28:02	2011-01-15 22:09:23	2011-01-15 22:09:23	CE4: Chroma interpolation using MOMS based FIR filters	H. Lakshman, H. Schwarz, D. Marpe, T. Wiegand (Fraunhofer HHI)
JCTVC-D058	m18805	2011-01-13 11:28:15	2011-01-15 02:52:24	2011-01-15 02:52:24	CE3: Verification of Nokia adaptive DCT-IF/DIF filters (JCTVC-D323)	Minhua Zhou
JCTVC-D059	m18806	2011-01-13 11:31:02	2011-01-15 03:06:18	2011-01-15 03:06:18	CE3: Verification of Samsung new 6-tap/8-tap DCT-IF filter	Minhua Zhou
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JCTVC-D104	m18855	2011-01-14 08:40:57	2011-01-15 13:29:48	2011-01-15 13:29:48	CE7: Cross check report of I2R's proposal (JCTVC-D046) from Toshiba	A. Tanizawa, J. Yamaguchi (Toshiba)
JCTVC-D105	m18856	2011-01-14 08:41:31	2011-01-15 13:31:41	2011-01-15 13:31:41	CE7: Cross check report of Samsung's proposal on mode-dependent DCT/DST (JCTVC-D033) from Toshiba	A. Tanizawa, J. Yamaguchi (Toshiba)
JCTVC-D106	m18857	2011-01-14 08:41:58	2011-01-14 12:06:41	2011-01-21 10:09:59	High Efficient 1 byte fixed length coding for Low Complexity Entropy Coding â€“ PIPE/V2F	Kazuo Sugimoto, Ryoji Hattori, Shun-ichi Sekiguchi, Yoshiaki Kato, Kohtaro Asai, Tokumichi Murakami (Mitsubishi)
JCTVC-D107	m18858	2011-01-14 08:42:05	2011-01-15 14:04:23	2011-01-20 06:42:46	CE7: Experimental results for one-dimensional directional unified transform (JCTVC-C080)	A. Tanizawa, J. Yamaguchi, T. Shiodera, T. Chujoh, T. Yamakage (Toshiba)

JCTVC-D108	m18859	2011-01-14 08:42:43	2011-01-15 13:33:36	2011-01-20 06:37:39	CE6 Subset A: Bidirectional intra prediction (JCTVC-C079)	T. Shiodera, A. Tanizawa, T. Chujoh, T. Yamakage (Toshiba)
JCTVC-D109	m18860	2011-01-14 08:42:49	2011-01-14 12:07:48	2011-01-23 01:04:47	LUT-based adaptive filtering on intra prediction samples	Kazuo Sugimoto, Shun-ichi Sekiguchi, Akira Minezawa (Mitsubishi), Kazuhisa Iguchi, Yoshiaki Shishikui (NHK),
JCTVC-D110	m18861	2011-01-14 08:43:11	2011-01-15 13:39:24	2011-01-15 13:39:24	CE6 Subset A: Cross check report of Samsung's proposal (JCTVC-D350) from Toshiba	A. Tanizawa, T. Shiodera (Toshiba)
JCTVC-D111	m18862	2011-01-14 08:43:40	2011-01-15 13:35:43	2011-01-15 13:35:43	CE6 Subset D: Cross check report of Sharp's proposal (JCTVC-D074) from Toshiba	A. Tanizawa, T. Shiodera (Toshiba)
JCTVC-D112	m18863	2011-01-14 08:53:24	2011-01-14 09:28:03	2011-01-22 02:01:47	Evaluation of Most Probable Mode	T. Yamamoto (SHARP)
JCTVC-D113	m18864	2011-01-14 08:53:57	2011-01-14 09:31:47	2011-01-24 10:33:49	CE11: Cross-check report for Fraunhofer HHI's proposal	Y. Yasugi, T. Yamamoto (SHARP)
JCTVC-D114	m18865	2011-01-14 08:54:13	2011-01-14 09:46:21	2011-01-19 13:01:49	CE8: Cross-check result of MQT_ALF - MediaTek, Qualcomm and Toshiba's joint proposal (JCT-VC D-119)	T. Ikai (SHARP)
JCTVC-D115	m18866	2011-01-14 08:54:31	2011-01-14 12:52:47	2011-01-26 08:07:10	CE8: DF-combined adaptive loop filter	T. Ikai, T. Yamazaki (SHARP)
JCTVC-D116	m18867	2011-01-14 08:54:49	2011-01-14 12:54:23	2011-01-23 01:04:40	Region-based adaptive loop filter using two-dimensional feature	T. Ikai, Y. Yasugi (SHARP)
JCTVC-D117	m18868	2011-01-14 09:13:25	2011-01-15 15:39:34	2011-01-15 15:39:34	CE9: Cross verification about the adaptation and modification (3.2.c) of the set of predictors	P. Onno
JCTVC-D118	m18870	2011-01-14 09:19:29	2011-01-14 14:25:29	2011-01-14 14:25:29	CE9: Report on experiment 3.1.h	Shigeru Fukushima
JCTVC-D119	m18871	2011-01-14 09:20:24	2011-01-15 02:19:36	2011-01-24 08:50:23	CE8 Subset2: A Joint Proposal on Improving the Adaptive Loop Filter in TMuC0.9 by MediaTek, Qualcomm, and Toshiba	C.-Y. Chen, C.-M. Fu, C.-Y. Tsai, Y.-W. Huang, S. Lei, M. Karczewicz, I. S. Chong, T. Yamakage, T. Chujoh, T. Watanabe
JCTVC-D120	m18872	2011-01-14 09:22:40	2011-01-15 14:45:23	2011-01-22 02:32:13	CE1:Refinement motion compensation using DMVD with merge extension	Motoharu Ueda
JCTVC-D121	m18873	2011-01-14 09:24:05	2011-01-15 16:22:21	2011-01-15 16:22:21	CE1:Cross-verification report of Samsung's Proposal by JVC KENWOOD	Motoharu Ueda, Satoru Sakazume,
JCTVC-D122	m18874	2011-01-14 09:24:47	2011-01-15 02:21:49	2011-01-24 08:54:36	CE8 Subset3: Picture Quadtree Adaptive Offset	C.-M. Fu, C.-Y. Chen, Y.-W. Huang, S. Lei
JCTVC-D123	m18875	2011-01-14 09:25:53	2011-01-15 02:23:30	2011-01-18 15:45:44	CE8 Subset3: Controlled Clipping	Y.-L. Chang, C.-M. Fu, Y.-W. Huang, S. Lei
JCTVC-D124	m18876	2011-01-14 09:27:14	2011-01-14 14:08:27	2011-01-19 12:43:22	CE6: Verification results of Huawei/ Hisilicon and Microsoft proposals JCTVC-D299	Jungsun Kim, Byeongmoon Jeon

JCTVC-D125	m18877	2011-01-14 09:27:19	2011-01-15 02:26:14	2011-01-23 01:23:20	Improved Advanced Motion Vector Prediction	J.-L. Lin, Y.-P. Tsai, Y.-W. Huang, S. Lei
JCTVC-D126	m18878	2011-01-14 09:28:19	2011-01-15 04:18:48	2011-01-23 14:21:26	Syntax for AMVP Parsing Error Control	J.-L. Lin, Y.-W. Huang, C.-M. Fu, C.-Y. Chen, Y.-P. Tsai, S. Lei
JCTVC-D127	m18879	2011-01-14 09:33:24	2011-01-15 04:38:52	2011-01-23 01:36:57	Syntax for Leaf Coding Unit Aligned Slices	C.-W. Hsu, C.-Y. Tsai, Y.-W. Huang, C.-Y. Chen, C.-M. Fu, S. Lei
JCTVC-D128	m18880	2011-01-14 09:35:27	2011-01-15 14:00:39	2011-01-23 01:45:11	Slice Boundary Processing and Picture Layer RBSP	C.-Y. Tsai, C.-W. Hsu, Y.-W. Huang, C.-Y. Chen, C.-M. Fu, S. Lei
JCTVC-D129	m18881	2011-01-14 09:38:06	2011-01-14 14:17:40	2011-01-19 12:44:58	Verification results of Samsung's proposals JCTVC-D365 on Fast Integer Transform	Jungsun Kim, Byeongmoon Jeon
JCTVC-D130	m18882	2011-01-14 09:38:10	2011-01-14 11:16:16	2011-01-26 07:39:37	CE9: verification of experiment 3.1.d	J. Jung, G. Clare
JCTVC-D131	m18883	2011-01-14 09:39:14	2011-01-15 02:30:33	2011-01-22 12:31:03	CE5: Crosscheck of Qualcomm's Modified LCEC in JCTVC-D370 by MediaTek	C.-Y. Chen, Y.-W. Huang
JCTVC-D132	m18884	2011-01-14 09:40:05	2011-01-14 11:16:47	2011-01-26 07:40:11	CE9: verification of experiment 3.1.e	J. Jung, G. Clare
JCTVC-D133	m18885	2011-01-14 09:41:09	2011-01-15 02:33:50	2011-01-22 12:46:04	CE9 3.1.g: Crosscheck of AMVP-based Skip/Direct and PU-based Merging by MediaTek	J.-L. Lin, Y.-W. Huang
JCTVC-D134	m18886	2011-01-14 09:41:43	2011-01-14 11:17:10	2011-01-26 07:40:42	CE9: verification of experiment 3.1.n	J. Jung, G. Clare
JCTVC-D135	m18887	2011-01-14 09:42:19	2011-01-15 02:35:44	2011-01-22 12:57:54	Crosscheck of Samsung and Qualcomm's Partial Frequency Transform in JCTVC-D257 by MediaTek	T.-D. Chuang, C.-Y. Chen, Y.-W. Huang
JCTVC-D136	m18888	2011-01-14 09:43:28	2011-01-15 02:37:47	2011-01-22 13:02:44	Crosscheck of LG and Qualcomm's Improvements on Median Motion Vectors of AMVP by MediaTek	C.-Y. Chen, J.-L. Lin, Y.-W. Huang
JCTVC-D137	m18889	2011-01-14 09:51:32	2011-01-15 16:23:28	2011-01-20 01:00:14	CE8, Subset 1: Report of Content-Adaptive Deblocking	Z. Shi (USTC), Z. Xiong (USTC), X. Sun (Microsoft), J. Xu (Microsoft)
JCTVC-D138	m18890	2011-01-14 09:51:54	2011-01-15 16:27:43	2011-01-20 01:01:05	Rounding control for Chroma interpolation	B. Li (USTC), J. Xu (Microsoft), G. J. Sullivan (Microsoft), F. Wu (Microsoft), H. Li (USTC)
JCTVC-D139	m18891	2011-01-14 09:52:10	2011-01-15 16:29:21	2011-01-23 03:36:07	Constrained temporal motion vector prediction for error resilience	B. Li (USTC), J. Xu (Microsoft), F. Wu (Microsoft), H. Li (USTC)
JCTVC-D140	m18892	2011-01-14 09:52:21	2011-01-15 16:34:33	2011-01-23 03:36:22	Adaptive coding order for skip and split flags in LCEC	B. Li (USTC), J. Xu (Microsoft), F. Wu (Microsoft), H. Li (USTC)
JCTVC-D141	m18893	2011-01-14 09:52:32	2011-01-15 16:35:56	2011-01-23 03:36:38	Improvement and extension of inter prediction direction and reference frame index combined coding in LCEC	B. Li (USTC), J. Xu (Microsoft), F. Wu (Microsoft), H. Li (USTC)
JCTVC-D142	m18894	2011-01-14 09:52:48	2011-01-15 16:41:34	2011-01-24 05:44:07	A unified design of RQT cbf coding in LCEC	B. Li (USTC), J. Xu (Microsoft), F. Wu (Microsoft), H. Li (USTC)

JCTVC-D143	m18895	2011-01-14 09:52:57	2011-01-15 16:42:24	2011-01-23 03:37:14	Results for redundancy reduction in PU-based merging	B. Li (USTC), J. Xu (Microsoft), F. Wu (Microsoft), H. Li (USTC)
JCTVC-D144	m18896	2011-01-14 09:53:07	2011-01-18 12:55:14	2011-01-25 04:10:52	CE8, Subset 1: Cross-verification report for NEC's proposal (JCTVC-D043)	Z. Shi (USTC), J. Xu (Microsoft)
JCTVC-D145	m18897	2011-01-14 09:53:17	2011-01-18 12:56:09	2011-01-25 04:12:19	CE6: Cross-verification report for Samsung and LG's proposal (JCTVC-D350)	J. Xu (Microsoft)
JCTVC-D146	m18898	2011-01-14 09:53:25	2011-01-20 00:53:11	2011-01-25 04:13:22	CE11: Cross-verification report for Samsung's proposal (JCTVC-D360)	J. Xu (Microsoft)
JCTVC-D147	m18899	2011-01-14 09:53:35	2011-01-18 13:10:46	2011-01-25 04:13:51	Cross-verification report for MediaTek's proposal (JCTVC-D166)	X. Peng (USTC), J. Xu (Microsoft)
JCTVC-D148	m18900	2011-01-14 09:53:45	2011-01-18 13:33:46	2011-01-25 04:14:36	Cross-verification report for Huawei's proposal on intra coding (JCTVC-D300 and JCTVC-D302)	J. Xu (Microsoft)
JCTVC-D149	m18901	2011-01-14 10:04:47	2011-01-17 16:49:11	2011-01-17 16:49:11	CE9: Summary report for CE9 on motion vector coding	J. Jung, B. Bross
JCTVC-D150	m18902	2011-01-14 10:26:17	2011-01-14 10:33:28	2011-01-14 10:33:28	Response to CE3: Region-based adaptive interpolation filter	Shohei Matsuo, Yukihiro Bandoh, Seishi Takamura, Hirohisa Jozawa
JCTVC-D151	m18903	2011-01-14 10:55:39	2011-01-15 07:31:31	2011-01-22 03:00:20	Mode Dependent 2-step Transform for Intra Coding	Youji Shibahara, Takahiro Nishi (Panasonic)
JCTVC-D152	m18904	2011-01-14 11:03:49	2011-01-16 02:54:28	2011-01-22 06:09:59	Adaptive scaling for bit depth compression on IBDI	T.Chujoh, T.Yamakage (Toshiba)
JCTVC-D153	m18905	2011-01-14 11:04:39	2011-01-14 11:07:39	2011-01-20 11:33:32	CE12: Cross-check result of Nokia's Proposal (JCTVC-D325) by Sejong Univ./SKT	Hyoungmee Park (SJU), Ju Ock Lee (SJU), Joo-Hee Moon (SJU), Jeongyeon Lim (SKT)
JCTVC-D154	m18906	2011-01-14 11:04:55	2011-01-15 11:31:38	2011-01-15 11:31:38	CE3: Non-uniform tap length filtering	T.Chujoh, K.Kanou, T.Yamakage (Toshiba)
JCTVC-D155	m18907	2011-01-14 11:06:55	2011-01-15 09:24:26	2011-01-18 10:49:06	Summary of CE3: interpolation for MC (Luma)	T.Chujoh (CE coordinator)
JCTVC-D156	m18908	2011-01-14 11:10:15	2011-01-15 08:09:18	2011-01-15 08:09:18	Verification of NEC's rounding-error conscious memory compression method for IBDI (JCTVC-D045)	T.Chujoh, T.Yamakage (Toshiba)
JCTVC-D157	m18909	2011-01-14 11:10:46	2011-01-17 01:00:13	2011-01-17 01:00:13	Verification of TI's evaluation results of IBDI (JCTVC-D025)	T.Chujoh, T.Yamakage (Toshiba)
JCTVC-D158	m18910	2011-01-14 11:11:16	2011-01-15 08:17:55	2011-01-19 14:47:41	CE3: Verification of Sony's Bi/Single MC interpolation filter (JCTVC-D090)	T.Chujoh, K.Kano, T.Yamakage (Toshiba)
JCTVC-D159	m18911	2011-01-14 11:11:45	2011-01-15 08:07:02	2011-01-17 07:19:35	CE3: Verification of Samsung's new 12-tap DCT-IF (JCTVC-D344)	T.Chujoh, K.Kano, T.Yamakage (Toshiba)
JCTVC-D160	m18912	2011-01-14 11:12:34	2011-01-17 07:09:03	2011-01-17 07:09:03	CE3: Verification of Qualcomm's 12/8-tap interpolation filter (JCTVC-D376)	T.Chujoh, K.Kano, T.Yamakage (Toshiba),

JCTVC-D161	m18913	2011-01-14 11:13:10	2011-01-18 04:18:37	2011-01-18 04:18:37	CE3: Verification of Nokia's complexity calculation of low complexity anchor (JCTVC-D322)	T.Chujoh, K.Kano, T.Yamakage (Toshiba),
JCTVC-D162	m18914	2011-01-14 11:13:51	2011-01-15 08:05:52	2011-01-15 08:05:52	CE4: Verification of Samsung's 4-tap DCT-IF Chroma	T.Chujoh, K.Kano, T.Yamakage (Toshiba)
JCTVC-D163	m18915	2011-01-14 11:27:34	2011-01-15 15:43:20	2011-01-15 15:43:20	CE8 Subtest1: Improved Deblocking Filter	Jicheng An, Xun Guo, Qian Huang, Yu-Wen Huang, Shawmin Lei,
JCTVC-D164	m18916	2011-01-14 11:28:23	2011-01-15 20:24:46	2011-01-21 08:24:47	Temporal MV predictor modification for MV-Comp, Skip, Direct and Merge schemes	J. Jung, G. Clare
JCTVC-D165	m18917	2011-01-14 11:29:02	2011-01-15 15:45:02	2011-01-15 15:45:02	CU-level Directional Merge Mode	Jicheng An, Xun Guo, Yu-Wen Huang, Shawmin Lei,
JCTVC-D166	m18918	2011-01-14 11:29:46	2011-01-15 15:45:51	2011-01-23 01:55:02	Improved Intra Mode Coding	Mei Guo, Xun Guo, Shawmin Lei,
JCTVC-D167	m18919	2011-01-14 11:30:42	2011-01-16 10:04:38	2011-01-21 08:11:54	CE1: Report of self derivation of motion estimation in TMuC 0.9	Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)
JCTVC-D168	m18920	2011-01-14 11:32:32	2011-01-15 19:12:31	2011-01-16 08:48:03	CE1: Cross-check of DMVD results from Mitsubishi (JCTVC-D099)	Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)
JCTVC-D169	m18921	2011-01-14 11:34:14	2011-01-15 19:15:53	2011-01-16 08:52:21	CE1: Cross-check of DMVD results from Huawei (JCTVC-D295)	Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)
JCTVC-D170	m18922	2011-01-14 11:35:45	2011-01-15 19:22:26	2011-01-16 09:39:10	CE8: Cross-check of MQT_ALF results from MediaTek, Qualcomm and Toshiba (JCTVC-D119)	Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)
JCTVC-D171	m18923	2011-01-14 11:36:36	2011-01-15 11:23:17	2011-01-19 15:35:13	Improved AIS filter	M. Budagavi (TI)
JCTVC-D172	m18924	2011-01-14 11:36:48	2011-01-15 19:23:23	2011-01-16 09:48:36	CE9: Cross-check of PU-based merge mode result (Test 3.1.g)	Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)
JCTVC-D173	m18925	2011-01-14 11:41:04	2011-01-14 11:44:16	2011-01-14 11:44:16	CE2-subset 4: Cross-check report of Technicolor's proposal on Geometry adaptive block partitioning Simplification from INRIA	L. Guillo, R. Boitard, (INRIA)
JCTVC-D174	m18926	2011-01-14 11:44:20	2011-01-16 09:56:27	2011-01-19 16:21:46	CE1: Summary Report of Decoder-Side Motion Vector Derivation	Yi-Jen Chiu, Haoping Yu, Yu-Wen Huang, Shun-ichi Sekiguchi
JCTVC-D175	m18927	2011-01-14 12:03:46	2011-01-15 07:42:59	2011-01-21 06:24:31	Bi-prediction combining template and block motion compensations	C.-L. Lee, C.-C. Chen, Y.-W. Chen, M.-H. Wu, C.-H. Wu, W.-H. Peng, H.-M. Hang (NCTU/ITRI)
JCTVC-D176	m18930	2011-01-14 12:14:08	2011-01-15 15:47:02	2011-01-15 15:47:02	CE13: Cross-verification of Qualcomm's simplified intra smoothing	J. Chen, J.-H. Min, W.-J. Han(Samsung)
JCTVC-D177	m18931	2011-01-14 12:19:40	2011-01-17 03:05:14	2011-01-17 03:05:14	CE6.c: Cross-check report on Differential Coding of Intra Modesï¼ˆDCIMï¼‰	Atsuro Ichigaya, Yasuko Sugito,
JCTVC-D178	m18932	2011-01-14 12:33:50	2011-01-14 12:44:36	2011-01-27 07:00:21	Impact of cascaded coding on HEVC	andrea.gabriellini@bbc.co.uk, david.flynn@rd.bbc.co.uk,

						thomas.davies@bbc.co.uk
JCTVC-D179	m18933	2011-01-14 12:34:39	2011-01-14 12:40:30	2011-01-14 12:40:30	CE3:Cross-check for NTT's proposal on Region-Based Adaptive Interpolation Filter (JCTVC-D150)	Tomonobu Yoshino, Sei Naito
JCTVC-D180	m18935	2011-01-14 12:44:18	2011-01-14 18:19:48	2011-01-22 18:14:37	Hardware Friendly Rotational Transform (CE7-related)	Xing Wen, Oscar C. Au, Lin Sun, Jiali Li, Feng Zou, Chao Pang, Jingjing Dai
JCTVC-D181	m18937	2011-01-14 13:03:47	2011-01-14 13:48:57	2011-01-22 16:53:17	Report on the evaluation of HM versus JM	Seungwook Park, Joonyoung Park, Byeongmoon Jeon
JCTVC-D182	m18939	2011-01-14 13:38:15	2011-01-15 11:39:57	2011-01-15 11:39:57	Performance report of adaptive DCT/DST selection	Atsuro Ichigaya, Shinichi Sakaida
JCTVC-D183	m18940	2011-01-14 14:08:30	2011-01-15 16:57:50	2011-01-15 16:57:50	CE8 Subset3: Cross verification on Picture Quadtree Adaptive Offset (JCTVC-D122)	I.-K. Kim, T. Lee (Samsung)
JCTVC-D184	m18941	2011-01-14 14:08:53	2011-01-15 11:34:51	2011-01-21 03:55:57	Reduced redundancy of the low complexity entropy coder (LCEC)	Hisao Sasai, Takahiro Nishi (Panasonic)
JCTVC-D185	m18942	2011-01-14 14:44:49	2011-01-15 11:35:25	2011-01-21 10:36:07	Simplified Context modeling for Transform Coefficient Coding	Hisao Sasai, Takahiro Nishi (Panasonic)
JCTVC-D186	m18943	2011-01-14 14:52:30	2011-01-15 11:36:07	2011-01-27 02:30:41	Unification of Transform Coefficient Coding for non-reference intra block	Hisao Sasai, Takahiro Nishi (Panasonic)
JCTVC-D187	m18945	2011-01-14 15:28:51	2011-01-14 16:01:52	2011-01-19 01:25:37	CE5: Cross-check results of Qualcomm and Cisco's proposal (JCTVC-D366) by ETRI	S.-C. Lim, H. Lee, H. Y. Kim (ETRI)
JCTVC-D188	m18946	2011-01-14 15:32:53	2011-01-17 03:58:42	2011-01-17 03:58:42	In-loop and post-processing filtering AHG: Verification results of TI's Proposal JCTVC-D039	T. Yamakage, T. Chujoh (Toshiba)
JCTVC-D189	m18948	2011-01-14 15:34:21	2011-01-15 19:05:05	2011-01-15 19:05:05	CE11: Cross-verification of Samsung's low-complexity adaptive coefficients scanning (JCTVC-C205)	V. Sze (TI)
JCTVC-D190	m18949	2011-01-14 15:35:01	2011-01-15 19:05:45	2011-01-21 04:51:21	CE11: Coding efficiency of tools in HHI_TRANSFORM_CODING (JCTVC-A116)	V. Sze (TI)
JCTVC-D191	m18950	2011-01-14 15:44:22	2011-01-15 23:57:01	2011-01-20 10:01:21	CE6: Report and evaluation of new Combined Intra Prediction settings	Marta Mrak, Thomas Davies, David Flynn, Andrea Gabriellini,
JCTVC-D192	m18951	2011-01-14 15:45:05	2011-01-15 02:48:05	2011-01-21 11:59:02	Analysis on the interaction between deblocking filtering and in-loop filtering	T. Yamakage, S. Asaka, A. Tanizawa, T. Watanabe, T. Chujoh (Toshiba),
JCTVC-D193	m18953	2011-01-14 15:50:03	2011-01-14 15:51:47	2011-01-23 00:44:35	Integration into the TMuC of an Intra Prediction based on a linear combination of Template Matching predictors	R. Boitard, L. Guillo, T. Poirier, (INRIA)
JCTVC-D194	m18954	2011-01-14 15:52:58	2011-01-17 18:18:43	2011-01-20 01:59:30	CE5: BBC cross-check of Samsung's proposal for LCEC improvements	Thomas Davies, David Flynn
JCTVC-D195	m18955	2011-01-14 15:56:30	2011-01-15 19:09:21	2011-01-21 03:53:40	CE11: Simplified context selection for significant_coeff_flag (JCTVC-C227)	V. Sze, M. Budagavi (TI)
JCTVC-D196	m18956	2011-01-14	2011-01-14	2011-01-14	CE6: Cross verification of Toshiba bidirectional intra prediction	J. Lainema, K. Ugur (Nokia)

		15:57:44	16:16:05	16:16:05		
JCTVC-D197	m18957	2011-01-14 15:57:48	2011-01-15 20:27:23	2011-01-21 07:20:50	Proposition for robust parsing with temporal predictor	J. Jung, G. Clare
JCTVC-D198	m18958	2011-01-14 15:59:58	2011-01-14 16:17:14	2011-01-14 16:17:14	CE10: Cross verification of directional intra prediction configurations	J. Lainema, K. Ugur (Nokia)
JCTVC-D199	m18959	2011-01-14 16:00:36	2011-01-14 16:17:36	2011-01-14 16:17:36	Configurable directional intra prediction	J. Lainema, K. Ugur (Nokia)
JCTVC-D200	m18960	2011-01-14 16:01:03	2011-01-15 01:05:09	2011-01-22 03:44:08	High layer syntax to improve support for temporal scalability	Jill Boyce, Danny Hong, Alexandros Eleftheriadis, (Vidyo)
JCTVC-D201	m18961	2011-01-14 16:01:26	2011-01-14 16:18:01	2011-01-20 08:37:53	Cross verification of Docomo intra coding improvements (D235)	J. Lainema, K. Ugur (Nokia)
JCTVC-D202	m18962	2011-01-14 16:02:05	2011-01-15 01:06:52	2011-01-25 03:08:19	1:2 Spatial Scalability Support for HEVC	Danny Hong, Jill Boyce, Alexandros Eleftheriadis, (Vidyo)
JCTVC-D203	m18963	2011-01-14 16:02:11	2011-01-15 11:19:26	2011-01-17 11:55:23	CE8 Subset1: Verification results of MadiaTek's Proposal JCTVC-D163	T. Yamakage (Toshiba)
JCTVC-D204	m18964	2011-01-14 16:04:16	2011-01-15 07:26:11	2011-01-19 06:38:36	CE6: Cross-check report on combined intra prediction	K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda
JCTVC-D205	m18965	2011-01-14 16:06:01	2011-01-15 07:24:34	2011-01-19 06:41:05	CE6: Cross-check report on differential coding of intra mode	K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda
JCTVC-D206	m18966	2011-01-14 16:07:52	2011-01-15 07:28:10	2011-01-15 07:28:10	CE8: Cross-check report on SKKU/SKT deblocking filter	K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda
JCTVC-D207	m18967	2011-01-14 16:09:08	2011-01-15 07:29:11	2011-01-15 07:29:11	CE10: Cross-check report on the number of intra prediction directions	K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda,
JCTVC-D208	m18968	2011-01-14 16:13:38	2011-01-15 07:34:07	2011-01-19 06:44:34	CE13: Cross-check report on HHI adaptive intra smoothing	K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda
JCTVC-D209	m18969	2011-01-14 16:20:49	2011-01-15 11:29:01	2011-01-19 06:46:22	Cross-check report on Sharp entropy slices (JCTVC-D070)	K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda
JCTVC-D210	m18970	2011-01-14 16:28:39	2011-01-15 11:32:32	2011-01-19 06:47:30	Study on Nokia planar intra prediction (JCTVC-D326)	K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda
JCTVC-D211	m18971	2011-01-14 16:32:51	2011-01-14 16:40:21	2011-01-14 16:40:21	CE8 Subset2: Verification results of Sharp's Proposal JCTVC-D115	T. Yamakage (Toshiba)
JCTVC-D212	m18972	2011-01-14 16:53:23	2011-01-17 02:26:46	2011-01-17 02:26:46	Verification results of Qualcomm's Proposal JCTVC-D262 on Parallel Context Processing	T. Yamakage (Toshiba)
JCTVC-D213	m18973	2011-01-14 16:58:13	2011-01-15 14:59:54	2011-01-26 09:53:43	In-loop reference frame denoising in HEVC reference software	Peter Amon, Eugen Wige, Andreas Hutter, Andre Kaup,
JCTVC-D214	m18974	2011-01-14	2011-01-15	2011-01-22	Reduction of operations in the critical path of the deblocking filter	Matthias Narroschke, Hisao Sasai,

		17:03:46	10:34:23	01:30:16		Thomas Wedi (Panasonic)
JCTVC-D215	m18975	2011-01-14 17:09:41	2011-01-15 10:35:15	2011-01-20 08:45:49	CE8: Cross-check results of the DF-combined adaptive loop filter of Sharp (JCTVC-D115)	Matthias Narroschke, Semih Esenlik (Panasonic)
JCTVC-D216	m18976	2011-01-14 17:10:10	2011-01-15 14:50:25	2011-01-20 08:52:13	CE8: Cross-check results of the adaptive loop filter of MediaTek, Qualcomm and Toshiba (JCTVC-D119)	Semih Esenlik, Matthias Narroschke (Panasonic)
JCTVC-D217	m18977	2011-01-14 17:15:03	2011-01-14 18:48:41	2011-01-22 09:41:32	CE 8: Results for adaptive loop filter using prediction and residual (3-Input-ALF)	Semih Esenlik, Matthias Narroschke, Thomas Wedi (Panasonic)
JCTVC-D218	m18978	2011-01-14 17:30:37	2011-01-15 19:45:47	2011-01-15 19:45:47	CE6.c: cross verification of edge-based intra prediction	Virginie Drugeon
JCTVC-D219	m18979	2011-01-14 17:34:38	2011-01-15 20:12:12	2011-01-21 13:04:55	Unified scan processing for high efficiency coefficient coding	Thomas Davies
JCTVC-D220	m18980	2011-01-14 17:35:48	2011-01-15 19:58:23	2011-01-15 19:58:23	Cross verification of Improved Chroma Intra mode Signaling	Virginie Drugeon
JCTVC-D221	m18981	2011-01-14 18:05:28	2011-01-15 22:16:18	2011-01-25 14:23:02	Loop filter with directional similarity mapping (DSM)	P. Lai, F. C. Fernandes (Samsung)
JCTVC-D222	m18982	2011-01-14 19:19:47	2011-01-15 07:54:16	2011-01-19 16:24:01	Performance of Rotational Transform (ROT) in TMuC 0.9	Xing Wen, Oscar C. Au, Lin Sun, Jingjing Dai, Feng Zou, Chao Pang
JCTVC-D223	m18983	2011-01-14 19:52:58	2011-01-15 20:37:37	2011-01-20 07:35:21	CE4: Interpolation filtering of chroma samples using two-stage averaging	A. Fuldseth, G. Bjøntegaard (Cisco)
JCTVC-D224	m18984	2011-01-14 19:56:43	2011-01-15 20:38:40	2011-01-22 02:17:42	Unified transform design for HEVC with 16 bit intermediate data representation	A. Fuldseth, G. Bjøntegaard (Cisco)
JCTVC-D225	m18985	2011-01-14 19:58:03	2011-01-15 20:39:19	2011-01-20 12:09:31	Directional interpolation filters for luma samples using 8 filter coefficients	A. Fuldseth, G. Bjøntegaard (Cisco)
JCTVC-D226	m18986	2011-01-14 19:59:03	2011-01-15 20:39:57	2011-01-20 12:25:14	Reducing the table sizes for LCEC	A. Fuldseth (Cisco)
JCTVC-D227	m18987	2011-01-14 19:59:51	2011-01-15 20:40:40	2011-01-21 03:41:38	Replacing slices with tiles for high level parallelism	A. Fuldseth (Cisco)
JCTVC-D228	m18988	2011-01-14 20:00:57	2011-01-15 20:41:08	2011-01-20 07:33:45	Cross-check of Qualcomm's proposal for improved coefficient coding for LCEC (JCTVC-D374)	A. Fuldseth (Cisco)
JCTVC-D229	m18989	2011-01-14 21:06:09	2011-01-16 21:24:19	2011-01-27 01:33:26	CE2: Summary of Core Experiment 2 on Flexible Motion Partitioning	E. Francois (Technicolor), X. Zheng (Huawei&Hisilicon), P. Chen (Qualcomm)
JCTVC-D230	m18990	2011-01-14 21:15:14	2011-01-15 19:03:54	2011-01-17 09:56:59	CE2: Simplified Geometry Block Partitioning	E. Francois, P. Bordes (Technicolor), L. Guo, M. Karczewicz (Qualcomm)
JCTVC-D231	m18991	2011-01-14 22:20:13	2011-01-15 08:22:19	2011-01-15 08:22:19	CE9: 3.2d Simplified motion vector prediction	A.Fujibayashi (NTT DOCOMO), F. Bossen (DOCOMO USA Labs)

JCTVC-D232	m18992	2011-01-14 22:32:30	2011-01-15 08:33:12	2011-01-15 08:33:12	CE9: Cross verification for subtest 3.3 temporal motion vector memory compression (JCTVC-D072)	A. Fujibayashi (NTT DOCOMO)
JCTVC-D233	m18993	2011-01-14 22:41:45	2011-01-15 15:18:50	2011-01-20 15:33:28	CE9: 3.1 PU merge & skip tools and proposed improvements	Y. Suzuki, TK Tan (NTT DOCOMO)
JCTVC-D234	m18994	2011-01-14 22:46:01	2011-01-15 06:27:43	2011-01-21 19:37:34	Random access support for HEVC	A. Fujibayashi, TK Tan (NTT DOCOMO)
JCTVC-D235	m18995	2011-01-14 23:04:36	2011-01-14 23:30:18	2011-01-22 16:00:31	Enhancements to Intra Coding	Sandeep Kanumuri, TK Tan, Frank Bossen
JCTVC-D236	m18996	2011-01-14 23:34:51	2011-01-15 03:38:17	2011-01-19 00:52:07	CE11: Cross-check report from Motorola Mobility for HHI's adaptive scan (JCTVC-A116)	Jian Lou, Krit Panusopone, Limin Wang
JCTVC-D237	m18997	2011-01-15 00:02:13	2011-01-15 11:21:27	2011-01-17 11:51:06	CE8 Subset2: Verification results of Panasonic's Proposal JCTVC-D217	T. Yamakage (Toshiba), I.S. Chong (Qualcomm), Y.W. Huang (MediaTek),
JCTVC-D238	m18999	2011-01-15 00:16:07	2011-01-15 20:46:56	2011-01-23 03:58:39	Removal of cabac_zero_word to simplify error detection in CABAC	Y. Matsuba, V. Sze (TI)
JCTVC-D239	m19000	2011-01-15 00:16:30	2011-01-15 03:39:13	2011-01-19 00:52:47	CE11: Report on Zigzag scan performance for CABAC on TMuC0.9	Jian Lou, Krit Panusopone, Limin Wang
JCTVC-D240	m19001	2011-01-15 00:17:44	2011-01-15 23:54:05	2011-01-21 01:25:10	CE11: Summary report on coefficient scanning and coding	V. Sze (TI), K. Panusopone (Motorola), J. Chen (Samsung), T. Nguyen (Fraunhofer HHI), M. Coban (Qualcomm)
JCTVC-D241	m19002	2011-01-15 00:18:27	2011-01-19 00:53:44	2011-01-21 11:17:53	Parallel processing friendly context modeling for significance map coding in CABAC	Jian Lou, Krit Panusopone, Limin Wang
JCTVC-D242	m19003	2011-01-15 00:19:05	2011-01-15 19:08:18	2011-01-15 19:08:18	Cross-check of Sony's simplified context selection (JCTVC-D260)	V. Sze (TI)
JCTVC-D243	m19004	2011-01-15 00:19:44	2011-01-16 04:25:30	2011-01-16 04:25:30	Analysis of entropy slice approaches	V. Sze, M. Budagavi (TI)
JCTVC-D244	m19005	2011-01-15 00:20:40	2011-01-16 04:04:15	2011-01-22 01:27:44	Context selection complexity in HEVC CABAC	V. Sze (TI)
JCTVC-D245	m19006	2011-01-15 00:28:08	2011-01-15 03:41:19	2011-01-19 00:53:15	Verification of TI's proposal on matrix multiplication architecture for DCT/IDCT	Jian Lou, Limin Wang
JCTVC-D246	m19007	2011-01-15 00:30:11	2011-01-20 06:38:16	2011-01-20 08:03:33	New DCT-based interpolation filters	Jian Lou, Limin Wang
JCTVC-D247	m19010	2011-01-15 01:28:31	2011-01-20 01:04:29	2011-01-20 01:04:29	CE1: Cross Check with JCTVC-C501 (3.1.2)	Yue Yu, Krit Panusopone, Limin Wang
JCTVC-D248	m19011	2011-01-15 01:31:52	2011-01-20 00:36:42	2011-01-20 00:36:42	CE9: Cross check with JCTVC-C509 (3.1.b)	Yue Yu, Krit Panusopone, Limin Wang
JCTVC-D249	m19012	2011-01-15	2011-01-15	2011-01-22	Super large coding tree block	Krit Panusopone, Xue Fang, Limin

		01:49:37	22:38:26	04:24:27		Wang
JCTVC-D250	m19013	2011-01-15 01:52:06	2011-01-15 21:51:26	2011-01-22 23:14:04	Efficient transform unit representation	Krit Panusopone, Xue Fang, Limin Wang
JCTVC-D251	m19014	2011-01-15 02:34:27	2011-01-15 17:58:42	2011-01-22 02:22:53	Intra prediction based on repetitive pixel replenishment with adaptive block size	Kenichi Iwata, Seiji Mochizuki, Ryoji Hashimoto,
JCTVC-D252	m19015	2011-01-15 02:42:26	2011-01-17 05:33:32	2011-01-22 02:14:19	Test Material for Screen Content coding	Wenpeng ding, Yunhui Shi, Baocai Yin,
JCTVC-D253	m19016	2011-01-15 02:46:42	2011-01-17 11:07:02	2011-01-22 02:11:48	Improved Intra Mode Coding by Multiple Mode Candidates	Wenpeng Ding, Xiaoyin Che, Yunhui Shi, Baocai Yin,
JCTVC-D254	m19017	2011-01-15 02:48:06	2011-01-18 03:40:43	2011-01-18 03:46:49	Enhenced Context Modeling for Skip and Split Flag	Xiaoyin Che, Wenpeng Ding, Yunhui Shi, Baocai Yin
JCTVC-D255	m19019	2011-01-15 03:07:32	2011-01-15 20:31:49	2011-01-22 01:00:35	Improved Chroma Intra Mode Signaling	L. Dong, W. Liu, A. Tabatabai
JCTVC-D256	m19020	2011-01-15 03:16:00	2011-01-16 07:30:35	2011-01-22 01:16:47	Efficient 16 and 32-point transforms	R. Joshi, Y. Reznik, J. Sole, M. Karczewicz
JCTVC-D257	m19021	2011-01-15 03:17:22	2011-01-16 05:52:03	2011-01-21 01:54:40	Low complexity 32Ã—32 transform by partial frequency transform	J. Sole, R. Joshi, M. Karczewicz, Y.-M. Hong, M.-S. Cheon, I.-K. Kim
JCTVC-D258	m19022	2011-01-15 03:23:26	2011-01-15 20:32:57	2011-01-22 01:02:07	CU Adaptive dQP Syntax Change for Better Decoder pipelining	L. Dong, W. Liu, K. Sato
JCTVC-D259	m19023	2011-01-15 03:31:38	2011-01-16 03:47:05	2011-01-21 00:03:07	CE6: Summary Report of Core Experiments for Intra Prediction	A. Tabatabai
JCTVC-D260	m19024	2011-01-15 03:34:39	2011-01-16 08:07:53	2011-01-18 05:29:49	Parallel processing friendly simplified context selection of significance map	C. Auyeung, W. Liu (Sony)
JCTVC-D261	m19025	2011-01-15 03:34:39	2011-01-15 20:36:10	2011-01-15 20:36:10	Improvements on transform coefficients coding in LCEC	J. Xu, M. Haque, A. Tabatabai
JCTVC-D262	m19026	2011-01-15 03:37:36	2011-01-16 09:19:37	2011-01-21 08:42:02	Parallel Context Processing for the significance map in high coding efficiency	J. Sole, R. Joshi, I.S. Chong, M. Coban, M. Karczewicz
JCTVC-D263	m19027	2011-01-15 03:43:39	2011-01-15 04:29:51	2011-01-22 02:22:46	Parallel deblocking filter	Masaru Ikeda, Junichi Tanaka, Teruhiko Suzuki
JCTVC-D264	m19028	2011-01-15 03:50:37	2011-01-16 03:10:23	2011-01-16 03:10:23	CE7: A crosscheck of Toshiba's proposal (JCTVC-D107) by Qualcomm	R. Joshi, P. Chen
JCTVC-D265	m19029	2011-01-15 03:52:58	2011-01-15 07:19:40	2011-01-15 07:19:40	Cross-check results of JCTVC-D234: random access support for HEVC	W.-J. Han (Samsung)
JCTVC-D266	m19031	2011-01-15 04:38:06	2011-01-15 16:41:40	2011-01-15 16:41:40	Investigation on Luma Interpolation Filter	Vivienne Sze, Minhua Zhou, Madhukar Budagavi
JCTVC-D267	m19032	2011-01-15	2011-01-16	2011-01-16	Crosscheck of Institute for Infocomm Research's temporal merge	R. Joshi, W.-J. Chien

		04:39:59	03:11:49	03:11:49	proposal (JCTVC-D051) by Qualcomm	
JCTVC-D268	m19033	2011-01-15 04:45:00	2011-01-15 11:25:02	2011-01-15 11:25:02	Verification of Cisco transform proposal (JCTVC-D224)	M. Budagavi (TI)
JCTVC-D269	m19034	2011-01-15 04:49:43	2011-01-15 23:28:59	2011-01-15 23:28:59	Verification of Qualcomm transform proposal (JCTVC-D256)	M. Budagavi (TI)
JCTVC-D270	m19035	2011-01-15 05:28:48	2011-01-16 03:13:16	2011-01-26 23:39:27	Low Complexity Parametric Adaptive Loop Filter	E. Maani, W. Liu, L. Dong
JCTVC-D271	m19036	2011-01-15 06:13:45	2011-01-15 06:16:30	2011-01-26 08:28:32	CE4 : Chroma Interpolation Filtering using High Precision Filter	Jeong-Pil Kim, Dae-Yeon Kim, Jeongyeon Lim, Yung-Lyul Lee
JCTVC-D272	m19037	2011-01-15 06:19:10	2011-01-15 06:20:50	2011-01-15 06:20:50	CE4 : Cross-check of Samsung's DCT-IF 6-tab chroma filtering	Jeong-Pil Kim, Dae-Yeon Kim, Heongyeon Lim, Yung-Lyul Lee
JCTVC-D273	m19038	2011-01-15 06:19:33	2011-01-15 06:36:47	2011-01-21 17:13:54	Modified derivation process of temporal motion vector predictor	Toshiyasu Sugio, Takahiro Nishi (Panasonic)
JCTVC-D274	m19039	2011-01-15 06:22:48	2011-01-15 06:37:22	2011-01-21 17:14:40	Modified usage of predicted motion vectors in forward directional bi-predictive coding frame	Toshiyasu Sugio, Takahiro Nishi (Panasonic)
JCTVC-D275	m19040	2011-01-15 06:37:32	2011-01-15 06:51:41	2011-01-20 07:03:35	Adaptive Coding of PredMode Syntax Elements	zhang.wen4@zte.com.cn, wang.dong@zte.com.cn, hong.yingjie@zte.com.cn, zuo.wen@zte.com.cn, li.ming42@zte.com.cn
JCTVC-D276	m19041	2011-01-15 07:00:31	2011-01-15 15:50:33	2011-01-22 06:42:14	Rate-Distortion Optimized Transforms for Intra Block Coding	F. Zou, O. C. Au, C. Pang, J. Dai, X. Zhang, X. Wen (HKUST)
JCTVC-D277	m19042	2011-01-15 07:02:56	2011-01-15 08:40:38	2011-01-15 08:40:38	CE9: Cross verfication of experiment 3.1.p	Seyoon Jeong, Hui Yong Kim, Jin Soo Choi, Kyungyong Kim, Sangmin Kim, Gwanghoon Park
JCTVC-D278	m19043	2011-01-15 07:07:15	2011-01-15 15:23:08	2011-01-22 11:38:20	Improved Signaling and Binarization of Chroma Intra Prediction Mode	J. Dai, O. C. Au, F. Zou, C. Pang, X. Wen (HKUST)
JCTVC-D279	m19044	2011-01-15 07:17:58	2011-01-16 03:30:19	2011-01-25 02:57:29	CE6.c: Summary and Improvements of DCIM	E. Maani, A. Tabatabai, T. Yamamoto, V. Drugeon
JCTVC-D280	m19045	2011-01-15 07:18:32	2011-01-15 09:59:54	2011-01-22 10:32:35	Performance report of DPCM-based memory compression on TMuC 0.9	H. Aoki, K. Chono, K. Senzaki, J. Tajime, Y. Senda (NEC)
JCTVC-D281	m19046	2011-01-15 07:42:00	2011-01-15 08:40:08	2011-01-17 08:55:00	Cross-verification of Toshiba's proposal on reference frame memory compression for IBDI	H. Aoki, K. Chono, K. Senzaki, J. Tajime, Y. Senda (NEC)
JCTVC-D282	m19047	2011-01-15 08:38:01	2011-01-16 09:18:38	2011-01-21 04:03:39	CE13: Mode Dependent Hybrid Intra Smoothing	Yunfei Zheng, Muhammed Coban, Marta Karczewicz
JCTVC-D283	m19048	2011-01-15 08:58:06	2011-01-16 04:05:24	2011-01-22 02:05:23	Further Encoder Improvement of intra mode decision	Liang Zhao, Li Zhang, Xin Zhao, Siwei Ma, Debin Zhao, Wen Gao,

JCTVC-D284	m19049	2011-01-15 09:00:43	2011-01-15 17:42:26	2011-01-20 10:00:07	CE7: Mode-dependent transform, residual reordering and coefficient scanning for intra prediction residue	Xin Zhao, Li Zhang, Siwei Ma, Wen Gao
JCTVC-D285	m19050	2011-01-15 09:07:08	2011-01-15 09:08:13	2011-01-23 07:12:10	Switching Interpolation Filter (SIF) scheme with low-complexity decision algorithm	T. Yoshino, S. Naito (KDDI)
JCTVC-D286	m19051	2011-01-15 09:08:29	2011-01-16 09:13:47	2011-01-22 02:02:46	Simplified multiplierless 4x4 DST for intra prediction residue	Xin Zhao, Li Zhang, Siwei Ma, Wen Gao
JCTVC-D287	m19053	2011-01-15 09:21:23	2011-01-15 09:26:08	2011-01-23 03:05:22	Bi-Intra Prediction using slope information	Chan-Won Seo, Jong-Ki Han, Jeong-Yeon Lim, Jin-Han Song
JCTVC-D288	m19054	2011-01-15 10:01:13	2011-01-15 15:46:36	2011-01-15 15:46:36	CE3: Crosscheck of Qualcomm's one-pass SIFO filtering for low complexity coding by MediaTek	Xun Guo, Jicheng An
JCTVC-D289	m19055	2011-01-15 10:02:03	2011-01-15 15:50:10	2011-01-15 15:50:10	CE4: Crosscheck of Qualcomm's 1/8 pel accuracy high precision filter interpolation filter for chroma by MediaTek	Jicheng An, Xun Guo
JCTVC-D290	m19056	2011-01-15 10:03:42	2011-01-15 15:50:50	2011-01-15 15:50:50	CE7: Crosscheck of PKU's proposal D284 by MediaTek	Xun Guo, Mei Guo
JCTVC-D291	m19057	2011-01-15 10:04:20	2011-01-15 15:51:49	2011-01-15 15:51:49	CE10 : Crosscheck report for number of intra by MediaTek	Mei Guo, Xun Guo
JCTVC-D292	m19058	2011-01-15 10:10:06	2011-01-15 15:53:13	2011-01-15 15:53:13	CE12 : Crosscheck of Nokia's adaptive MV resolution by MediaTek	Xun Guo, Jicheng An
JCTVC-D293	m19059	2011-01-15 10:12:26	2011-01-15 15:54:20	2011-01-15 15:54:20	Toshiba : Crosscheck of Toshiba's deblocking filter in D192 by MediaTek	Jicheng An, Xun Guo
JCTVC-D294	m19060	2011-01-15 10:13:37	2011-01-15 15:55:21	2011-01-15 15:55:21	CE3 : Crosscheck of Qualcomm's 12/8 tap interpolation filter by MediaTek	Jicheng An, Xun Guo
JCTVC-D295	m19061	2011-01-15 10:27:31	2011-01-15 14:26:04	2011-01-22 01:10:17	CE1: Huawei report on TMDMVD and STDM in HM	Mingyuan Yang, Sixin Lin, Haoping Yu
JCTVC-D296	m19062	2011-01-15 10:38:34	2011-01-15 10:56:23	2011-01-22 05:24:07	Unbiased clipping for IBDI	H. Aoki, K. Chono, K. Senzaki, J. Tajime, Y. Senda (NEC)
JCTVC-D297	m19063	2011-01-15 10:38:48	2011-01-15 14:30:09	2011-01-27 07:04:02	CE2: Huawei & HiSilicon report on Flexible Motion Partitioning	X. Zheng (HiSilicon), H. Yu (Huawei)
JCTVC-D298	m19064	2011-01-15 10:41:00	2011-01-15 14:33:11	2011-01-15 14:33:11	CE2: Cross-verification of AMP from Samsung	X. Zheng (HiSilicon), H. Yu (Huawei)
JCTVC-D299	m19065	2011-01-15 10:51:12	2011-01-15 14:38:45	2011-01-20 06:51:21	CE6.b Report on Short Distance Intra Prediction Method	X. Cao (Tsinghua), X. Peng (USTC), C. Lai (HiSilicon), Y. Wang (Tsinghua), Y. Lin (HiSilicon), J. Xu (Microsoft), L. Liu (HiSilicon), J. Zheng (HiSilicon), Y. He (Tsinghua), H. Yu (Huawei), F. Wu (Microsoft)
JCTVC-D300	m19066	2011-01-15	2011-01-15	2011-01-21	Improved Intra prediction for positive directions in UDI	Y. Lin, C. Lai, J. Zheng, L. Liu

		10:54:08	14:44:34	15:21:19		
JCTVC-D301	m19067	2011-01-15 10:54:59	2011-01-15 14:46:53	2011-01-20 23:17:36	CE9: Result of 3.2.c	Kazushi Sato
JCTVC-D302	m19068	2011-01-15 10:57:58	2011-01-15 14:42:52	2011-01-21 15:23:28	Intra coding improvements for slice boundary blocks	Y. Lin, C. Lai, J. Zheng, L. Liu
JCTVC-D303	m19069	2011-01-15 10:59:05	2011-01-15 14:48:06	2011-01-22 00:24:06	Consideration on AMVP	Kazushi Sato
JCTVC-D304	m19070	2011-01-15 11:00:54	2011-01-15 14:47:19	2011-01-20 16:28:31	CE7: Simplified MDDT scheme using symmetry-based scanning orders	H. Yang, J. Zhou, H. Yu
JCTVC-D305	m19071	2011-01-15 11:04:00	2011-01-15 14:50:27	2011-01-18 09:36:21	CE13: Cross-Check Result of 3.2d	Kazushi Sato
JCTVC-D306	m19072	2011-01-15 11:04:14	2011-01-15 14:49:05	2011-01-20 16:41:46	CE7: Crosscheck of I2R's proposal by Huawei	H. Yang, J. Zhou
JCTVC-D307	m19073	2011-01-15 11:06:47	2011-01-15 14:52:44	2011-01-20 08:01:17	CE7: Cross-checking of MDDT results from Qualcomm	J. Song, H. Yang,
JCTVC-D308	m19074	2011-01-15 11:08:47	2011-01-15 14:51:09	2011-01-22 00:29:29	On LBS and Quantization	Kazushi Sato
JCTVC-D309	m19075	2011-01-15 11:13:33	2011-01-15 14:54:20	2011-01-20 16:51:59	CE11: Cross-check of Motorola's proposal JCTVC-D239 by Huawei	H. Yang, J. Zhou
JCTVC-D310	m19076	2011-01-15 11:18:42	2011-01-15 14:57:59	2011-01-26 08:09:51	Cross-check results of MSRA's proposals JCTVC-D138, D140, D141 and D142 by Huawei	J. Zhou, H. Yang
JCTVC-D311	m19077	2011-01-15 11:21:51	2011-01-15 14:59:31	2011-01-20 12:37:12	Adaptive coefficients scanning for inter-frame coding	J. Song, M. Yang, H. Yang, J. Zhou, D. Wang, S. Lin, H. Yu
JCTVC-D312	m19078	2011-01-15 11:25:28	2011-01-15 15:01:14	2011-01-22 03:13:35	Fine granularity slice partition	Q. Shen, Q. Xie, H. Yu
JCTVC-D313	m19079	2011-01-15 11:42:04	2011-01-15 12:23:07	2011-01-26 08:10:53	CE13: Intra Smoothing Test Report	B. Bross, D. Marpe, H. Schwarz, T. Wiegand (Fraunhofer HHI)
JCTVC-D314	m19080	2011-01-15 11:44:58	2011-01-15 20:21:40	2011-01-15 20:21:40	CE9: Motion Vector Coding Test Report	B. Bross, S. Oudin, D. Marpe, H. Schwarz, T. Wiegand (Fraunhofer HHI),
JCTVC-D315	m19081	2011-01-15 12:00:17	2011-01-15 20:22:18	2011-01-21 02:49:20	Crosscheck of NTT DOCOMO's Proposal JCTVC-D233 on Merge Improvements	B. Bross (Fraunhofer HHI)
JCTVC-D316	m19082	2011-01-15 12:01:14	2011-01-15 20:22:49	2011-01-17 15:41:31	Crosscheck of MediaTek's Proposal JCTVC-D165 on CU-level Directional Merge Mode	B. Bross (Fraunhofer HHI)
JCTVC-D317	m19083	2011-01-15 12:20:39			Withdrawn - duplicate registration for JCTVC-D327	
JCTVC-D318	m19084	2011-01-15	2011-01-15	2011-01-15	CE4: Cross verification of high precision chroma interpolation filter	K. Ugur, J. Lainema (Nokia)

		12:21:59	12:59:43	12:59:43		
JCTVC-D319	m19085	2011-01-15 12:23:05	2011-01-15 13:22:06	2011-01-15 13:22:06	CE5: Cross verification of Qualcomm's counter adaptation for LCEC tool	K. Ugur, J. Lainema (Nokia)
JCTVC-D320	m19086	2011-01-15 12:25:05	2011-01-15 18:09:27	2011-01-15 18:09:27	CE11: Cross verification of Samsung's proposal JCTVC-C205	K. Ugur (Nokia)
JCTVC-D321	m19087	2011-01-15 12:25:55	2011-01-15 17:25:27	2011-01-21 08:14:23	High precision bi-directional averaging	K. Ugur, J. Lainema, A. Hallapuro (Nokia)
JCTVC-D322	m19088	2011-01-15 12:27:12	2011-01-15 13:27:19	2011-01-15 13:27:19	CE3: On complexity calculation of low complexity anchor	K. Ugur (Nokia)
JCTVC-D323	m19089	2011-01-15 12:30:19	2011-01-15 15:15:18	2011-01-15 15:15:18	CE3: Results for luma interpolation filter tests by Nokia and Qualcomm	K. Ugur, J. Lainema, A. Hallapuro (Nokia), M. Karczewicz, I. S. Chong, L. Guo (Qualcomm),
JCTVC-D324	m19090	2011-01-15 12:31:40	2011-01-15 17:46:00	2011-01-15 17:46:00	CE4: Results for chroma interpolation filter tests by Nokia	K. Ugur, J. Lainema (Nokia)
JCTVC-D325	m19091	2011-01-15 12:32:22	2011-01-15 13:30:20	2011-01-15 13:30:20	CE 12: Nokia proposal on adaptive MV resolution with directional filters	K. Ugur, J. Lainema (Nokia)
JCTVC-D326	m19092	2011-01-15 12:33:10	2011-01-15 13:36:06	2011-01-21 01:11:59	Planar intra coding for improved subjective video quality	J. Lainema, K. Ugur, O. Bici (Nokia)
JCTVC-D327	m19093	2011-01-15 12:56:39	2011-01-15 12:58:00	2011-01-15 12:58:00	CE3: Cross verification of MOMS interpolation filter	K. Ugur, J. Lainema (Nokia)
JCTVC-D328	m19094	2011-01-15 13:29:48	2011-01-15 13:55:06	2011-01-16 15:03:49	CE2: cross-checking of Asymmetric motion partitioning with OBMC proposal from Samsung and Qualcomm	E. Francois, P. Bordes (Technicolor)
JCTVC-D329	m19095	2011-01-15 14:42:05	2011-01-15 14:47:32	2011-01-15 14:47:32	CE1: Samsung's test for bi-directional optical flow	Elena Alshina, Alexander Alshin, Woo-Jin Han
JCTVC-D330	m19096	2011-01-15 15:02:01	2011-01-16 17:42:19	2011-01-22 05:00:51	CE9: Cross-verification result of (3.1.j) by SKKU	Jungyoup Yang, Kwanghyun Won, Byeungwoo Jeon (Sungkyunkwan University)
JCTVC-D331	m19097	2011-01-15 15:08:56	2011-01-15 15:10:30	2011-01-15 15:10:30	Cross verification on scalable motion vector competition and simplified MVP calculation (JCTVC-D055) from TI	I.-K. Kim, T. Lee (Samsung)
JCTVC-D332	m19098	2011-01-15 15:16:30	2011-01-16 05:07:43	2011-01-16 05:07:43	CE8 subset 1: Cross-verification result of Microsoft proposal by SKKU/SKT	Jungyoup Yang, Kwanghyun Won, Heechul Yang, Byeungwoo Jeon (Sungkyunkwan Univ.), Jeongyeon Lim (SK Telecom)
JCTVC-D333	m19099	2011-01-15 15:18:44	2011-01-15 15:21:11	2011-01-15 15:21:11	Cross verification on Improved AMVP (JCTVC-D125) from MediaTek	I.-K. Kim, T. Lee (Samsung)
JCTVC-D334	m19100	2011-01-15 15:21:55	2011-01-16 05:18:25	2011-01-26 03:28:18	CE8 subset 1: Results of intra deblocking filter testing by SKKU/SKT (JCTVC-C130)	Jungyoup Yang, Kwanghyun Won, Heechul Yang, Byeungwoo Jeon

						(Sungkyunkwan Univ.), Jeongyeon Lim (SK Telecom),
JCTVC-D335	m19101	2011-01-15 15:24:13	2011-01-15 15:27:19	2011-01-15 15:27:19	Cross verification on constrained temporal motion vector prediction for error resilience (JCTVC-D139) from Microsoft	I.-K. Kim, T. Lee (Samsung)
JCTVC-D336	m19102	2011-01-15 15:49:32	2011-01-16 00:29:30	2011-01-26 08:47:32	Reduced-complexity entropy coding of transform coefficient levels using a combination of VLC and PIPE	T. Nguyen, M. Winken, D. Marpe, H. Schwarz, T. Wiegand
JCTVC-D337	m19103	2011-01-15 15:58:12	2011-01-15 16:00:22	2011-01-15 16:00:22	Improved motion vector predictor selection in AMVP	I.-K. Kim, T. Lee (Samsung)
JCTVC-D338	m19104	2011-01-15 16:01:39	2011-01-15 19:29:24	2011-01-15 19:29:24	Withdrawn - Duplicate registration	
JCTVC-D339	m19105	2011-01-15 16:03:23	2011-01-15 19:27:40	2011-01-22 02:14:31	Fast, Mult-Free Transforms for the HM	Wei Dai, Madhu Krishnan, Pankaj Topiwala
JCTVC-D340	m19106	2011-01-15 16:09:04	2011-01-15 16:11:23	2011-01-15 16:11:23	CE1: Cross-verification of Kenwood's experimental results of refinement motion compensation using DMVD (JCTVC-D120) by Samsung	E. Alshina, W.-J. Han, A. Alshin (Samsung)
JCTVC-D341	m19107	2011-01-15 16:19:22	2011-01-15 16:21:57	2011-01-15 16:21:57	CE3: Cross-verification of Qualcomm's experimental results for Luma interpolation using SIFO6 by Samsung	E. Alshina, W.-J. Han, J. Chen (Samsung)
JCTVC-D342	m19108	2011-01-15 16:21:47	2011-01-26 20:14:00	2011-01-26 20:14:00	More improvements and results of the arithmetic coding based on probability aggregation	Hongbo Zhu
JCTVC-D343	m19109	2011-01-15 16:32:13	2011-01-15 16:39:36	2011-01-15 16:39:36	CE3: Cross-verification of Toshiba's experimental results for NTLF with DCTIF 12/8 by Samsung	E. Alshina, W.-J. Han, J. Chen (Samsung)
JCTVC-D344	m19110	2011-01-15 16:43:21	2011-01-15 16:49:52	2011-01-20 08:42:19	CE3: Experimental results of DCTIF by Samsung	E. Alshina, jianle.chen@samsung.comm, alexander_b.alshin@samsung.com, n.shlyakhov@samsung.com, W.-J. Han (Samsung)
JCTVC-D345	m19111	2011-01-15 17:15:29	2011-01-15 17:17:18	2011-01-19 14:19:32	Summary of CE4: interpolation for MC (Chroma)	E. Alshina (Samsung)
JCTVC-D346	m19112	2011-01-15 17:20:41	2011-01-15 18:49:06	2011-01-17 02:47:58	CE4: Cross-verification of HHI's experimental results for Chroma interpolation using MOMS by Samsung	E. Alshina, W.-J. Han, J. Chen (Samsung)
JCTVC-D347	m19113	2011-01-15 17:34:54	2011-01-15 17:37:39	2011-01-15 17:37:39	CE4: Experimental results of DCTIF application for Chroma MC by Samsung	J. Chen, E. Alshina, W.-J. Han (Samsung)
JCTVC-D348	m19114	2011-01-15 17:41:43	2011-01-15 17:44:51	2011-01-15 17:44:51	CE6.a: Cross-verification of intra prediction improvement from Santa Clara University and Hisilicon (JCTVC-D026)	J. Chen, J.-H. Min (Samsung)
JCTVC-D349	m19115	2011-01-15 17:42:56	2011-01-15 17:46:03	2011-01-15 17:46:03	CE4: High Precision Filtering for Chroma	P. Chen, M. Karczewicz
JCTVC-D350	m19116	2011-01-15	2011-01-15	2011-01-20	CE6.a: Chroma intra prediction by reconstructed luma samples	J. Chen, V. Seregin, S. Lee, W.-J. Han

		17:47:28	17:50:01	17:19:44		(Samsung), J. Kim, B. Jeon (LG),
JCTVC-D351	m19118	2011-01-15 18:17:09	2011-01-15 18:28:27	2011-01-15 18:28:27	CE4: Cross-check for Cisco's Proposal	P. Chen, M. Karczewicz
JCTVC-D352	m19120	2011-01-15 18:47:09	2011-01-15 23:31:44	2011-01-15 23:31:44	High accuracy averaging for bi-prediction (Verification of D321)	F. Bossen, S. Kanumuri (DOCOMO USA Labs)
JCTVC-D353	m19121	2011-01-15 18:51:41	2011-01-15 18:54:11	2011-01-15 18:54:11	CE7: Cross-verification of I2R's experimental results of low complexity MDDT by Samsung	E. Alshina, W.-J. Han, A. Saxena (Samsung)
JCTVC-D354	m19122	2011-01-15 18:55:52	2011-01-15 18:58:38	2011-01-18 14:06:14	CE7: Cross-verification of Qualcomm's MDDT	E. Alshina, V. Seregin, W.-J. Han (Samsung)
JCTVC-D355	m19123	2011-01-15 18:56:05	2011-01-15 18:58:23	2011-01-15 18:58:23	CE9: Cross-check report from Qualcomm on Modified AMVP and PU-Merge (CE9.3.1c)	W.-J. Chien, M. Karczewicz
JCTVC-D356	m19124	2011-01-15 18:57:19	2011-01-15 21:13:33	2011-01-27 01:40:46	Three digits to speed up the reference encoder	F. Bossen (DOCOMO USA Labs)
JCTVC-D357	m19125	2011-01-15 19:02:19	2011-01-15 19:04:06	2011-01-15 19:04:06	CE7: Experimental results of fast ROT by Samsung	E. Alshina, A. Alshin, F.-C. Fernandes, Y. Piao, W.-J. Han (Samsung)
JCTVC-D358	m19127	2011-01-15 19:07:07	2011-01-15 19:09:04	2011-01-15 19:09:04	CE10: Samsung's crosscheck on number of intra prediction directions	J.-H. Min, J. Chen (Samsung)
JCTVC-D359	m19129	2011-01-15 19:11:01	2011-01-15 19:15:23	2011-01-15 19:15:23	CE11: Cross-verification of Qualcomm's low-complexity adaptive coefficients scanning	V. Seregin, J. Chen (Samsung)
JCTVC-D360	m19134	2011-01-15 19:29:13	2011-01-15 19:34:09	2011-01-26 08:11:39	CE11: Low-complexity adaptive coefficients scanning	V. Seregin, J. Chen, W.-J. Han (Samsung)
JCTVC-D361	m19136	2011-01-15 19:36:26	2011-01-15 19:39:23	2011-01-15 19:39:23	CE12: Cross-verification of Qualcomm's experimental results of AMVRES by Samsung	E. Alshina, W.-J. Han, A. Saxena (Samsung)
JCTVC-D362	m19137	2011-01-15 19:40:33	2011-01-16 09:41:31	2011-01-16 09:41:31	CE12: Summary Report of Adaptive Motion Vector Resolution	W.-J. Chien
JCTVC-D363	m19138	2011-01-15 19:41:13	2011-01-15 19:42:39	2011-01-15 19:42:39	CE13: cross-verification on HHI's fast adaptive intra smoothing	J. Chen, J.-H. Min (Samsung)
JCTVC-D364	m19139	2011-01-15 20:05:11	2011-01-16 08:26:14	2011-01-16 08:26:14	CE5: Summary report of CE5 on LCEC	X. Wang (Qualcomm), A. Fuldseth (Cisco)
JCTVC-D365	m19140	2011-01-15 20:15:12	2011-01-15 20:17:59	2011-01-22 04:19:18	Fast Integer Transforms for the HM, and Complexity Analysis	Y.-M. Hong, I.-K. Kim, K.-H. Lee (Samsung), W. Dai, M. Krishnan, P. Topiwala (FastVDO)
JCTVC-D366	m19141	2011-01-15 20:16:19	2011-01-16 08:25:08	2011-01-20 10:19:45	CE5: Improved intra prediction mode coding with LCEC	M. Karczewicz, X. Wang, W.-J. Chen (Qualcomm), A. Fuldseth (Cisco)
JCTVC-D367	m19142	2011-01-15 20:24:16	2011-01-15 22:00:20	2011-01-15 22:00:20	CE2: Asymmetric motion partition with overlapped block motion compensation	M.-S. Cheon, I.-K. Kim, L. Guo, P. Chen, M. Karczewicz,

JCTVC-D368	m19143	2011-01-15 20:24:26	2011-01-15 22:16:54	2011-01-25 01:14:58	CE2: Overlapped Block Motion Compensation for Geometry Partition Block	L. Guo, P. Chen, M. Karczewicz(Qualcomm),
JCTVC-D369	m19144	2011-01-15 20:25:12	2011-01-15 20:27:36	2011-01-20 12:44:19	CE5: Efficient coefficient coding method for 16x16 and 32x32 transforms in LCEC mode	S. Lee, I.-K. Kim, W.-J. Han, J.-H. Park, J. Chen (Samsung)
JCTVC-D370	m19145	2011-01-15 21:24:42	2011-01-16 08:23:45	2011-01-20 09:51:51	CE5: Improved coding of inter prediction mode with LCEC	W.-J. Chen, X. Wang, M. Karczewicz (Qualcomm),
JCTVC-D371	m19147	2011-01-15 21:41:20	2011-01-16 06:26:39	2011-01-16 06:26:39	Crosscheck of TI's matrix multiplication specification (JCTVC-D036) and DCT+Hadamard large transform (JCTVC-D037) by Qualcomm	R. Joshi, Y. Zheng, J. Sole
JCTVC-D372	m19148	2011-01-15 21:42:53	2011-01-15 22:59:30	2011-01-15 22:59:30	CE3: Cross check of Toshiba's luma interpolation filter JCTVC-D154	H. Lakshman (Fraunhofer HHI)
JCTVC-D373	m19149	2011-01-15 21:46:47	2011-01-15 23:28:56	2011-01-19 16:06:36	CE4: Cross check of Nokia's chroma interpolation filter JCTVC-D324	H. Lakshman (Fraunhofer HHI)
JCTVC-D374	m19150	2011-01-15 21:54:44	2011-01-16 09:05:24	2011-01-26 06:48:21	CE5: Improved coefficient coding with LCEC	M. Karczewicz, X. Wang, W.-J. Chien (Qualcomm)
JCTVC-D375	m19152	2011-01-15 22:04:52	2011-01-16 10:06:11	2011-01-23 02:25:27	LCEC coded block flag coding under residual quadtree	X. Wang, W.-J. Chien, M. Karczewicz (Qualcomm)
JCTVC-D376	m19153	2011-01-15 22:05:14	2011-01-16 04:45:21	2011-01-20 06:51:50	CE3: Qualcomm's proposal for luma interpolation filters	I. S. Chong, L. Guo, M. Karczewicz,
JCTVC-D377	m19154	2011-01-15 22:56:23	2011-01-16 02:39:26	2011-01-24 06:49:46	Development of HEVC deblocking filter	A. Norkin, K. Andersson, R. Sjöberg (Ericsson)
JCTVC-D378	m19155	2011-01-15 22:56:50	2011-01-15 23:05:03	2011-01-20 15:37:56	Generalized slices	M. Horowitz, S. Xu (eBrisk Video)
JCTVC-D379	m19156	2011-01-16 00:02:38	2011-01-16 00:45:16	2011-01-25 03:12:23	CE8 Subset1: Cross verification of Mediatek's deblocking filter by Ericsson	K. Andersson, A. Norkin, R. Sjöberg (Ericsson)
JCTVC-D380	m19157	2011-01-16 00:02:50	2011-01-16 00:06:31	2011-01-22 03:52:07	Reduced complexity PIPE coding using systematic v2v codes	Heiner Kirchhoffer, Detlev Marpe, Heiko Schwarz, Christian Bartnik, Anastasia Henkel, Mischa Siekmann, Jan Stegemann, Thomas Wiegand,
JCTVC-D381	m19158	2011-01-16 00:09:21	2011-01-16 01:25:20	2011-01-16 01:30:56	CE5: Cross-check of Qualcomm's intra mode coding for LCEC by Sony	J. Xu, A. Tabatabai
JCTVC-D382	m19159	2011-01-16 00:09:57	2011-01-16 08:09:37	2011-01-17 23:26:16	CE11: Cross-verification of Samsung's low-complexity adaptive coefficients scanning (JCTVC-C205)	C. Auyeung
JCTVC-D383	m19160	2011-01-16 00:10:44	2011-01-16 01:39:39	2011-01-16 01:39:39	Simplification of end-of-slice coding for arithmetic coding	F. Bossen (DOCOMO USA Labs)
JCTVC-D384	m19162	2011-01-16 00:12:08	2011-01-16 00:45:07	2011-01-23 01:26:51	Quantization with Hard-decision Partition and Adaptive Reconstruction Levels for low delay setting	Xiang Yu, Jing Wang, Da-ke He, En-hui Yang (RIM)
JCTVC-D385	m19163	2011-01-16	2011-01-16	2011-01-26	Adaptive Loop Filtering Using Multiple Filter Shapes	faouzi@ebriskvideo.com, N. Mahdi, H.

		00:14:34	00:22:52	16:15:14		Guermazi, M. A. BenAyed (eBrisk Video Inc)
JCTVC-D386	m19164	2011-01-16 00:17:22	2011-01-16 00:39:15	2011-01-22 02:50:32	Constrained Intra source code implementation	Rickard Sjöberg, Jonatan Samuelsson (Ericsson)
JCTVC-D387	m19165	2011-01-16 00:19:16	2011-01-16 00:40:07	2011-01-16 00:40:07	Cross-verification of D127: Leaf Coding Unit Aligned Slices	Rickard Sjöberg, Per Wennersten (Ericsson)
JCTVC-D388	m19166	2011-01-16 00:19:51	2011-01-16 08:06:43	2011-01-16 08:06:43	Cross check of JCTVC-D037 on DCT+Hadamard large transform	C. Auyeung
JCTVC-D389	m19168	2011-01-16 01:26:28	2011-01-16 01:36:53	2011-01-20 23:59:27	CE6.c: Experimental results of DCIM	E. Maani, A. Tabatabai, T. Yamamoto
JCTVC-D390	m19169	2011-01-16 01:31:45	2011-01-16 09:00:20	2011-01-21 03:59:05	CE13: Summary report on intra smoothing	M. Coban, B. Bross, J. Chen
JCTVC-D391	m19170	2011-01-16 01:44:09	2011-01-16 03:10:26	2011-01-25 04:52:53	Improvement of Adaptive Intra Smoothing by Switching Interpolation Filters	E. Maani, A. Tabatabai
JCTVC-D392	m19171	2011-01-16 02:10:32	2011-01-16 02:42:16	2011-01-21 09:48:12	CE7: Mode dependent intra residual coding - A joint proposal based on several proposals from CE7	R. Joshi, P. Chen, M. Karczewicz, A. Tanizawa, J. Yamaguchi, C. Yeo, Y. Tan, H. Yang, H. Yu
JCTVC-D393	m19172	2011-01-16 02:11:54	2011-01-16 09:39:59	2011-01-26 21:53:17	CE11: Mode Dependent Coefficient Scanning	Yunfei Zheng, Muhammed Coban, Xianglin Wang, Joel Sole, Rajan Joshi, Marta Karczewicz
JCTVC-D394	m19173	2011-01-16 02:12:13	2011-01-16 09:06:40	2011-01-16 09:06:40	CE12: Adaptive Motion Vector Resolution from Qualcomm	W.-J. Chien, P. Chen, M. Karczewicz
JCTVC-D395	m19174	2011-01-16 02:45:07	2011-01-16 02:49:14	2011-01-23 07:59:55	Comments on chroma deblocking bug fix 119 and WD1 draft text	A. Norkin, S. Sjöberg (Ericsson)
JCTVC-D396	m19175	2011-01-16 04:44:59	2011-01-16 08:43:52	2011-01-22 01:37:49	On Slice Granularity	Y. Chen, P. Chen, M. Karczewicz
JCTVC-D397	m19176	2011-01-16 06:35:42	2011-01-16 06:40:39	2011-01-20 01:23:13	A New Adaptive Interpolation Filtering Technique	faouzi@ebriskvideo.com, N. Mahdi, M. A. Ben Ayed (eBrisk Video Inc), ,
JCTVC-D398	m19177	2011-01-16 06:51:49	2011-01-16 06:55:35	2011-01-16 06:55:35	CE6: Cross verification of Samsung chroma intra prediction	M. Coban
JCTVC-D399	m19178	2011-01-16 07:00:27	2011-01-16 07:02:45	2011-01-21 04:21:32	CE7: Mode dependent intra residual coding analysis	P. Chen, R. Joshi, Y. Zheng, M. Coban, M. Karczewicz
JCTVC-D400	m19179	2011-01-16 07:16:58	2011-01-16 07:17:46	2011-01-16 07:17:46	CE11: Cross verification of Motorola's zigzag scan for CABAC/PIPE	M. Coban
JCTVC-D401	m19180	2011-01-16 08:38:57	2011-01-16 08:53:20	2011-01-16 08:53:20	Comments on Generalized P and B Pictures	Y. Chen, M. Coban, W.-J. Chien, M. Karczewicz
JCTVC-D402	m19181	2011-01-16	2011-01-16	2011-01-16	CE13: Intra Smoothing Test Report	M. Coban, Y. Zheng, M. Karczewicz

		08:56:46	08:57:42	08:57:42		
JCTVC-D403	m19182	2011-01-16 09:04:45	2011-01-17 02:10:42	2011-01-17 02:10:42	CE5: Cross-check of Qualcomm/Cisco's proposal on improved intra prediction mode coding in LCEC	Y. H. Tan, C. Yeo, Z. Li (I2R)
JCTVC-D404	m19183	2011-01-16 11:06:29	2011-01-20 08:44:28	2011-01-27 08:28:02	HEVC Reference Software Manual	F. Bossen, D. Flynn, K. Suehring (AHG chairs)
JCTVC-D405	m19184	2011-01-16 12:25:57	2011-01-16 12:37:15	2011-01-16 12:40:24	CE2: Cross-check results of Huawei & HiSilicon's proposal	J.Kim, J.Lee, H.Y.Kim
JCTVC-D406	m19186	2011-01-16 15:50:54	2011-01-17 21:31:02	2011-01-27 09:21:10	Cross-verification of SONY's proposal on low complexity parametric adaptive loop filter (JCTVC-D270)	M. Zhou (TI)
JCTVC-D407	m19198	2011-01-17 05:05:16	2011-01-20 07:00:01	2011-01-20 07:00:01	Verification of mode dependent intra residual coding(JCTVC-D392)	Seungwook Park, Jaehyun Lim, Byeongmoon Jeon
JCTVC-D408	m19199	2011-01-17 05:36:15	2011-01-18 15:16:16	2011-01-18 15:16:16	Crosscheck of Samsung and FastVDO's proposal JCTVC-D365 on simplified quantization/dequantization matrices	Xin Zhao, Li Zhang, Siwei Ma, Wen Gao
JCTVC-D409	m19201	2011-01-17 06:32:41	2011-01-17 07:33:52	2011-01-17 07:33:52	CE7: A crosscheck of Samsung's fast ROT proposal (JCTVC-D357) by Qualcomm	P. Chen, R. Joshi
JCTVC-D410	m19204	2011-01-17 07:00:41	2011-01-17 08:27:04	2011-01-17 08:27:04	CE9: Cross verification result on subtest 3.1.o (JCTVC-D233) of NTT DOCOMO	I.-K Kim, T. Lee (Samsung)
JCTVC-D411	m19205	2011-01-17 07:04:56	2011-01-17 08:31:42	2011-01-17 08:31:42	CE9: Test results on subtest 3.1.s and 3.1.t	I.-K Kim, T. Lee (Samsung)
JCTVC-D412	m19208	2011-01-17 08:19:52	2011-01-17 08:26:47	2011-01-17 09:00:01	CE1: Cross-check result on Bi-directional optical flow of Samsung (JCTVC-D329)	E. Y. Son, J. W. Jung, S. H. Yea (LG)
JCTVC-D413	m19224	2011-01-17 09:55:48	2011-01-18 11:53:31	2011-01-22 00:21:37	CE9: cross-check result of 3.1s and 3.1t	Yoshitaka Morigami, Kazushi Sato
JCTVC-D414	m19237	2011-01-17 12:03:52	2011-01-17 12:11:20	2011-01-17 12:11:20	CE3 : Cross-check report of Toshiba's Non-uniform tap length filter(JCTVC-D154)	J. W. Jung, E. Y. Son, S. H. Yea (LG)
JCTVC-D415	m19240	2011-01-17 12:13:23	2011-01-17 12:14:10	2011-01-17 12:14:10	CE4: Cross-check report of Nokia's Chroma interpolation filter(JCTVC-D324)	J. W. Jung, E. Y. Son, S. H. Yea (LG)
JCTVC-D416	m19261	2011-01-17 14:23:07	2011-01-17 14:27:20	2011-01-23 05:28:35	LCEC RDOQ speedup	V.Seregin, J.Chen(Samsung)
JCTVC-D417	m19364	2011-01-18 08:37:09	2011-01-21 06:48:25	2011-01-21 06:48:25	Cross-check report of Sony's AMVP modification (JCTVC-D303)	Tomoyuki Yamamoto, Yukinobu Yasugi (SHARP)
JCTVC-D418	m19369	2011-01-18 12:51:06	2011-01-26 09:44:44	2011-01-26 09:44:44	CE2: Cross-verification report for Huawei's proposal (JCTVC-D297)	J. Xu (Microsoft)
JCTVC-D419	m19372	2011-01-18 13:43:46	2011-01-18 13:51:03	2011-01-18 13:51:03	CE3: Verification of Qualcomm's and Nokia's switching 8 taps low bit-depth interpolation filter by Samsung	Elena Alshina, Woo-Jin Han, Jianle Chen
JCTVC-D420	m19379	2011-01-18	2011-01-19	2011-01-24	Huawei & HiSilicon report on CE4: Experimental results of DCTIF	Lingzhi Liu, Yongbing Lin, Haoping Yu

		20:55:36	01:05:55	03:46:39	application for Chroma MC by Samsung	
JCTVC-D421	m19400	2011-01-20 01:13:09	2011-01-20 01:36:16	2011-01-25 07:56:31	Extension of uni-prediction simplification in B slices	Y. Suzuki, TK Tan (NTT DOCOMO), W. J. Chien, Y. Chen, P. Chen, M. Coban (Qualcomm)
JCTVC-D422	m19401	2011-01-20 01:16:16	2011-01-20 01:38:09	2011-01-20 01:38:09	CE4: Cross-verification of Samsung 4-tap DCT-IF chroma filter	K. Ugur (Nokia)
JCTVC-D423	m19402	2011-01-20 06:38:50	2011-01-20 06:41:03	2011-01-27 00:46:41	CE3: Verification results of Samsung's 8 Tap DCTIF with 6 bits coefficients under Encoder Restriction by Qualcomm	L. Guo, I. Chong, M. Karczewicz (Qualcomm)
JCTVC-D424	m19403	2011-01-20 08:12:34	2011-01-21 01:28:15	2011-01-21 01:28:15	CE11: Cross-check results for Qualcomm's Proposal JCTVC-D393	T. Nguyen, D. Marpe, H. Schwarz, T. Wiegand
JCTVC-D425	m19404	2011-01-20 08:25:53	2011-01-20 10:34:44	2011-01-20 10:34:44	Cross-check report of HKUST's proposal JCTVC-D276 by ZJU	X. Zhu, S. Li, (ZJU)
JCTVC-D426	m19405	2011-01-20 08:27:19	2011-01-21 03:50:13	2011-01-21 03:50:13	Cross check report of HKUST's JCTVC-D278 Proposal by ASTRI	Carmen Cheng (ASTRI)
JCTVC-D427	m19408	2011-01-20 09:52:43	2011-01-27 07:56:30	2011-01-27 07:56:30	CE2: Crosscheck of Qualcomm's proposal of JCTVC-D368 by MediaTek	Jicheng An, Xun Guo
JCTVC-D428	m19409	2011-01-20 10:43:04	2011-01-20 16:52:48	2011-01-20 16:52:48	Cross-check report of Sony's proposal JCTVC-D303 by Panasonic	Toshiyasu Sugio, Takahiro Nishi (Panasonic)
JCTVC-D429	m19410	2011-01-20 10:56:23	2011-01-21 04:16:02	2011-01-21 04:16:02	Cross-check results for HHI's Proposal JCTVC-D336	Y. Zheng, M. Coban
JCTVC-D430	m19415	2011-01-21 03:01:59	2011-01-21 03:03:46	2011-01-22 01:22:44	Evaluation of Entropy Slices	M. Coban, M. Karczewicz
JCTVC-D431	m19416	2011-01-21 03:41:55	2011-01-21 08:40:17	2011-01-21 08:40:17	Crosscheck of Orange's Temporal MV predictor modification Proposal 2.2 JCTVC-D164	B.Bross (Fraunhofer HHI)
JCTVC-D432	m19418	2011-01-21 08:42:39	2011-01-21 08:52:01	2011-01-21 08:52:01	Remove Partition Size NxN	S. Liu, Y.-W. Huang, S. Lei,
JCTVC-D433	m19425	2011-01-22 02:26:55	2011-01-22 02:36:39	2011-01-22 11:59:46	Cross-check for Motorola Mobility's Proposal D250 on Efficient Transform Unit Representation by RIM	Jinwen Zan (RIM), Dake he (RIM)
JCTVC-D434	m19426	2011-01-22 03:07:29	2011-01-22 13:12:35	2011-01-22 13:12:35	Cross verification of Ericsson's proposal JCTVC-D377 by Nokia	K.Ugur (Nokia)
JCTVC-D435	m19428	2011-01-22 03:24:34	2011-01-27 07:14:23	2011-01-27 07:14:23	Cross verification of JCTVC-D365 by Nokia	K. Ugur (Nokia)
JCTVC-D436	m19433	2011-01-22 10:22:47	2011-01-23 02:30:58	2011-01-24 04:27:54	Crosscheck of Peking University's proposal (JCTVC-D283)	M. Guo, X. Li, X. Guo (MediaTek)
JCTVC-D437	m19435	2011-01-22 17:03:37	2011-01-23 00:47:01	2011-01-23 03:23:56	Cross-check for Samsung Electronics's Proposal JCTVC-D416 on LCEC RDOQ speedup by RIM	Jing Wang, Dake He (RIM)

JCTVC-D438	m19436	2011-01-22 17:49:14	2011-01-22 17:51:11	2011-01-24 15:46:29	Directional interpolation filter: alternative directions for f, i, k, q	Hongbo Zhu
JCTVC-D439	m19438	2011-01-23 02:53:39	2011-01-23 07:18:39	2011-01-23 07:18:39	Cross verification of Panasonic proposal JCTVC-D273	M. Zhou (TI)
JCTVC-D440	m19441	2011-01-23 05:29:34	2011-01-23 07:45:08	2011-01-23 07:45:08	Evaluation results on TPE	M. Zhou (TI)
JCTVC-D441	m19449	2011-01-23 17:20:44	2011-01-24 06:04:33	2011-01-24 06:31:45	BoG report of CE9: Motion Vector Coding	T. K. Tan (NTT DOCOMO), W.-J. Han (Samsung), B. Bross (Fraunhofer HHI), J. Jung (Orange Labs), K. McCann (Samsung), Y. Suzuki (NTT DOCOMO), G. Clare (Orange Labs), H. Schwarz (Fraunhofer HHI), A. Fujibayashi (NTT DOCOMO),
JCTVC-D442	m19453	2011-01-24 05:49:27	2011-01-24 16:15:58	2011-01-24 16:15:58	Cross-verification results for JCTVC-D421	B. Li (USTC), J. Xu (Microsoft)
JCTVC-D443	m19457	2011-01-24 09:10:45	2011-01-24 09:13:48	2011-01-24 09:13:48	BoG report on Intra Prediction Improvements	Ali Tabatabai
JCTVC-D444	m19459	2011-01-24 09:36:57	2011-01-24 10:27:38	2011-01-24 11:28:49	Cross-check on Qualcom's new RDOQ for LCEC	David Flynn, Thomas Davies
JCTVC-D445	m19461	2011-01-24 11:22:22	2011-01-24 11:32:17	2011-01-27 04:29:39	Draft of proposed new CE10: Core Transform Design	Pankaj Topiwala, Madhukar Budagavi, Rajan Joshi, Arild Fuldseth, Ilkoo Kim
JCTVC-D446	m19465	2011-01-24 17:08:08	2011-01-24 17:46:16	2011-01-24 17:46:16	CE1: Cross-verification report for the part of JCTVC-D167 proposed by Intel	Motoharu Ueda
JCTVC-D447	m19466	2011-01-24 17:31:35	2011-01-24 17:40:44	2011-01-24 17:40:44	BoG Report on Alternative Transforms	R. Cohen, C. Yeo, R. Joshi, F. Fernandes
JCTVC-D448	m19473	2011-01-25 06:19:11	2011-01-25 06:55:50	2011-01-26 02:02:06	CE1 Subtest1: A joint proposal of candidate-based decoder-side motion vector derivation	Y.-J. Chiu, L.Xu, W. Zhang, H. Jiang (Intel), M. Yang, S. Lin, H. Yu (Huawei)
JCTVC-D449	m19474	2011-01-25 06:24:28	2011-01-25 06:28:12	2011-01-25 06:28:12	Cross-verification of Microsoft's method in JCTVC-D140 based CE9.3.1.t software	T.Lee, J.Chen(Samsung)
JCTVC-D450	m19475	2011-01-25 07:41:03	2011-01-26 01:21:28	2011-01-26 01:21:28	Cross-check report on harmonized DMVD technique (JCTVC-D448)	Shun-ichi Sekiguchi, Kazuo Sugimoto(Mitsubishi)
JCTVC-D451	m19477	2011-01-26 03:18:26	2011-01-27 03:31:38	2011-01-27 03:31:38	Report on bugfix for CABAC sub-block coding reported in JCTVC-D027	T. Nguyen, K. Suehring
JCTVC-D452	m19479	2011-01-26 04:29:27	2011-01-26 04:44:27	2011-01-27 01:34:05	Cross checking of JCTVC-D186 on unification of transform coefficient coding for non-reference intra block	A. Tabatabai, C. Auyeung (Sony)
JCTVC-D453	m19480	2011-01-26 05:29:02	2011-01-26 05:31:03	2011-01-26 07:26:44	Cross-check report of mode dependent transform coefficients scanning from JCTVC-D393	J.Chen, V.Sze, K.Panusopone, A.Tabatabai, M.Coban

JCTVC-D454	m19482	2011-01-26 08:48:11	2011-01-27 00:40:57	2011-01-27 00:40:57	Cross-check results of the parallel deblocking filter of Sony (JCTVC-D263)	Matthias Narroschke (Panasonic)
JCTVC-D455	m19483	2011-01-26 09:39:01	2011-01-27 01:16:30	2011-01-27 01:16:30	Cross-check results of the deblocking filter of Panasonic (JCTVC-D214)	Teruhiko Suzuki, Masaru Ikeda
JCTVC-D456	m19485	2011-01-27 02:22:26	2011-01-27 02:32:28	2011-01-27 02:32:28	CE11: Crosscheck of Qualcomm's Mode Dependent Coefficient Scanning in JCTVC-D393 by MediaTek	C.-Y. Chen, Y.-W. Huang
JCTVC-D457	m19489	2011-01-27 04:04:36	2011-01-27 09:33:17	2011-01-27 09:33:17	BoG report on deblocking filter - subjective viewing and decoder run-time	Rickard Sjoberg (Ericsson), David Flynn (BBC)
JCTVC-D458	m19490	2011-01-27 04:31:20	2011-01-27 09:04:06	2011-01-27 10:09:29	BoG report on Screen Content Coding (SCC)	O. C. Au (HKUST), J. Xu (Microsoft), H. Yu (Huawei),
JCTVC-D459	m19501	2011-01-27 15:57:56	2011-01-27 16:07:09	2011-01-27 16:07:09	Withdrawn	A. Norkin,
JCTVC-D460	m19502	2011-01-27 16:19:55			Withdrawn	T. Yamakage
JCTVC-D600	m19497	2011-01-27 09:17:05	2011-02-14 19:09:18	2011-02-14 19:09:18	Common test conditions and software reference configurations	F. Bossen
JCTVC-D601	m19500	2011-01-27 14:54:40	2011-01-27 14:58:43	2011-02-18 20:39:43	Description of Core Experiment 1 (CE1): Decoder-Side Motion Vector Derivation	Y.-J. Chiu (Intel), H. Yu (Huawei), Y.-W. Huang (Mediatek), S. Sekiguchi (Mitsubishi)
JCTVC-D602	m19488	2011-01-27 03:22:01	2011-01-27 14:21:27	2011-02-12 16:41:26	Description of Core Experiment 2 (CE2): Flexible Motion Partitioning	X. Zheng, P. Bordes, P. Chen, I.-K Kim, (CE Coordinators)
JCTVC-D603	m19492	2011-01-27 06:01:57	2011-01-27 11:06:11	2011-02-18 10:04:28	Description of Core Experiment 3 (CE3): Interpolation for MC (Luma)	T.Chujoh, E.Alshina (CE Coordinators)
JCTVC-D604	m19504	2011-01-27 16:51:45	2011-01-27 16:54:09	2011-02-17 15:52:56	Description of Core Experiment 4 (CE4): Slice Boundary Processing and Fine Granularity	Y.-W. Huang (MediaTek), I.-K. Kim (Samsung)
JCTVC-D605	m19495	2011-01-27 07:12:46	2011-01-27 15:19:56	2011-02-14 02:09:35	Description of Core Experiment 5 (CE5): Low Complexity Entropy Coding Improvements	X. Wang, I. K. Kim, P. Wu
JCTVC-D606	m19509	2011-01-28 03:10:40	2011-01-28 03:49:30	2011-02-19 02:06:08	Description of Core Experiment 6 (CE6): Intra Prediction Improvement	Ali Tabatabai
JCTVC-D607	m19494	2011-01-27 06:47:20	2011-01-27 09:06:52	2011-02-28 19:46:40	Description of Core Experiment 7 (CE7): Alternative Transforms	R. Cohen, C. Yeo, R. Joshi, F. Fernandes
JCTVC-D608	m19503	2011-01-27 16:23:54	2011-01-27 16:42:46	2011-02-13 08:01:18	Description of Core Experiment 8 (CE8): Non-deblocking loop filtering	T. Yamakage, Y. W. Huang, I. S. Chong, T. Ikai, M. Narroschke, W. L. Lai
JCTVC-D609	m19484	2011-01-27 01:58:07	2011-01-27 13:54:16	2011-02-14 10:52:07	Description of Core Experiment 9 (CE9): MV Coding and Skip/Merge operations	J. Jung, B. Bross
JCTVC-D610	m19491	2011-01-27	2011-01-27	2011-02-14	Description of Core Experiment 10 (CE10): Core Transform Design	P. Topiwala (FastVDO), M. Budagavi

		04:47:40	04:50:44	22:34:26		(TI), A. Fuldseth (Cisco), R. Joshi (Qualcomm), I.-K. Kim (Samsung)
JCTVC-D611	m19499	2011-01-27 10:32:55	2011-01-27 10:33:53	2011-02-12 01:21:46	Description of Core Experiment 11 (CE11): Coefficient scanning and coding	V. Sze (TI), K. Panusopone (Motorola), J. Chen (Samsung), T. Nguyen (Fraunhofer HHI), M. Coban (Qualcomm)
JCTVC-D612	m19508	2011-01-28 02:44:28	2011-01-28 03:01:05	2011-02-11 17:49:51	Description of Core Experiment 12 (CE12): Deblocking filtering	A. Norkin (Ericsson), B. Jeon (SKKU), M. Narroschke (Panasonic)
JCTVC-D613	m19506	2011-01-27 17:05:44	2011-01-27 17:06:30	2011-02-17 15:53:18	Description of Core Experiment 13 (CE13): Sample Adaptive Offset	Y.-W. Huang
JCTVC-D614	m19505	2011-01-27 17:01:45	2011-01-27 17:02:14	2011-02-11 09:14:48	Description of Core Experiment 14 (CE14): Intra Mode Coding	S. Lei, M. Karczewicz, TK Tan, W. Ding, G. Li

Annex B to JCT-VC report:
List of meeting participants

The participants of the third meeting of the JCT-VC, according to a sign-in sheet circulated during the meeting (approximately 248 in total), were as follows:

1. Kyofumi Abe (Panasonic)
2. Sangsoo Ahn (KAIST)
3. Yongjo Ahn (Kwangwoon Univ.)
4. Elena Alshina (Samsung)
5. Peter Amon (Siemens)
6. Kenneth Andersson (Ericsson)
7. Hirofumi Aoki (NEC)
8. Kohtaro Asai (Mitsubishi Electric)
9. Oscar Au (Hong Kong Univ. Sci. & Tech.)
10. Cheung Auyeung (Sony)
11. Yukihiro Bandoh (NTT)
12. Gun Bang (ETRI)
13. Oguz Bici (Nokia)
14. Gisle Bjøntegaard (Cisco Systems)
15. Ronan Boitard (INRIA)
16. Philippe Bordes (Technicolor)
17. Frank Bossen (DoCoMo USA Labs)
18. Jill Boyce (Vidyo)
19. Benjamin Bross (Fraunhofer HHI)
20. Madhukar Budagavi (Texas Instruments Inc)
21. Soo-Ik Chae (Seoul Natl. Univ.)
22. Jianle Chen (Samsung)
23. Peisong Chen (Qualcomm)
24. Weizhong Chen (Huawei)
25. Ying Chen (Qualcomm)
26. Wei-Jung Chien (Qualcomm)
27. Yi-Jen Chiu (Intel)
28. Seunghyun Cho (ETRI)
29. Sukhee Cho (ETRI)
30. Yoonsik Choe (Yonsei Univ.)
31. Haechul Choi (Hanbat Univ.)
32. Hyomin Choi (Kwangwoon Univ.)
33. Jin Soo Choi (ETRI)
34. Kiho Choi (Hanyang Univ.)
35. Soonwoo Choi (Seoul Natl. Univ.)
36. Younghee Choi (LG Electronics)
37. In Suk Chong (Qualcomm)
38. Keiichi Chono (NEC)
39. Takeshi Chujoh (Toshiba)
40. Sorin Cismas (Maxim Integrated Products)
41. Gordon Clare (Orange Labs)
42. Muhammed Coban (Qualcomm)
43. Robert Cohen (Mitsubishi Electric)
44. Thomas Davies (BBC R&D)
45. Wenping Ding (Beijing Univ. Tech.)
46. Virginie Drugeon (Panasonic)
47. Semih Esenlik (Panasonic)
48. Felix Fernandes (Samsung)
49. David Flynn (BBC)
50. Chad Fogg (Harmonic)
51. Edouard François (Technicolor)
52. Deliang Fu (Zhejiang Univ.)
53. Akira Fujibayashi (NTT DoCoMo)
54. Shigeru Fukushima (JVC Kenwood)
55. Arild Fuldseth (Cisco Systems)
56. Laurent Guillo (INRIA)
57. Mei Guo (MediaTek)
58. Xun Guo (MediaTek)
59. Antti Hallapuro (Nokia)
60. Jong-Ki Han (Sejong Univ.)
61. Woo-Jin Han (Samsung)
62. Miska Hannuksela (Nokia)
63. Munsi Haque (Sony USA)
64. Dzung Hoang (Zenverge, Inc.)
65. Danny Hong (Vidyo, Inc.)
66. Soongi Hong (Yonsei Univ.)
67. Sung-Wook Hong (Sejong Univ.)
68. Yingjie Hong (ZTE)
69. Michael Horowitz (Vidyo, Inc.)
70. Chih-Wei Hsu (MediaTek)
71. Yu-Wen Huang (MediaTek)
72. Yan Huo (ASTRI)
73. Atsuro Ichigaya (NHK)
74. Tomohiro Ikai (Sharp)

75. Kenichi Iwata (Renesas)
76. Euy-Doc Jang (Korea Aerosp. Univ.)
77. Byeungwoo Jeon (Sungkyunkwan Univ.)
78. Yong-Joon Jeon (LG Electronics)
79. Seyoon Jeong (ETRI)
80. Hyunho Jo (Kwangwoon Univ.)
81. Rajan Joshi (Qualcomm)
82. Dongsan Jun (ETRI)
83. Ji Wook Jung (LG)
84. Joël Jung (Orange Labs)
85. Jung Won Kang (ETRI)
86. Sandeep Kanumuri (Docomo USA Labs)
87. Marta Karczewicz (Qualcomm)
88. Kimihiko Kazui (Fujitsu)
89. Hae Kwang Kim (Sejong Univ.)
90. Hui Yong Kim (ETRI)
91. Il Koo Kim (Samsung)
92. Jae-Gon Kim (Korea Aerosp. Univ.)
93. Jaeil Kim (KAIST)
94. Jaeseok Kim (Yonsei Univ.)
95. Jeong-Pil Kim (Sejong Univ.)
96. Jongho Kim (ETRI)
97. Jongho Kim (Yonsei Univ.)
98. Jungsun Kim (LG)
99. Kyungyong Kim (Kyunghee Univ.)
100. Munchurl Kim (KAIST)
101. Sangmin Kim (Kyunghee Univ.)
102. Seongwan Kim (Yonsei Univ.)
103. Taeryong Kim (Kyunghee Univ.)
104. Youngseop Kim (Dankook Univ.)
105. Younhee Kim (ETRI)
106. Sven Klomp (Leibniz Univ. Hannover)
107. Tomoya Kodara (Toshiba)
108. Kenji Kondo (Sony)
109. Faouzi Kossentini (eBrisk Video)
110. Jumpei Koyama (Fujitsu)
111. Andreas Krutz (Tech. Univ. Berlin)
112. MiJeone Kwon (Samsung Electronics)
113. Changcai Lai (Huawei)
114. PoLin (Wang) Lai (Samsung)
115. Jani Lainema (Nokia)
116. Haricharan Lakshman (Fraunhofer HHI)
117. Guillaume Laroche (Canon)
118. Chulhee Lee (KCC/Yonsei Univ.)
119. Hahyun Lee (ETRI)
120. Hyobin Lee (Yonsei Univ.)
121. Jae-Young Lee (Sejong Univ.)
122. Jinho Lee (ETRI)
123. Jonghwa Lee (Yonsei Univ.)
124. Ju Ock Lee (Sejong Univ.)
125. Sang-Yong Lee (Korea Aerosp. Univ.)
126. Sangyoun Lee (Yonsei Univ.)
127. Sukho Lee (ETRI)
128. Sunil Lee (Samsung Electronics)
129. Yoonjin Lee (Kyunghee Univ.)
130. YungGi Lee (Pixtree)
131. Yung-Lyul Lee (Sejong Univ.)
132. Shawmin Lei (MediaTek)
133. Bin Li (USTC)
134. Guichun Li (Huawei)
135. Ming Li (ZTE)
136. Shangwen Li (Zhejiang Univ.)
137. Chongsoon Lim (Panasonic Singapore Labs)
138. Jaehyun Lim (LG Electronics)
139. Jeongyeon Lim (SK Telecom)
140. Sung-Chang Lim (ETRI)
141. Jian-Liang Lin (MediaTek)
142. Sixin Lin (Huawei)
143. Sungwon Lin (Sejong Univ.)
144. Lingzhi Liu (Huawei / Hisilicon)
145. Shan Liu (MediaTek)
146. Sadufule Manyesh (TI)
147. Detlev Marpe (Fraunhofer HHI)
148. Gaëlle Martin-Cocher (RIM)
149. Mona Mathur (STMicroelectronics)
150. Shohei Matsuo (NTT)
151. Ken McCann (Zetacast / Samsung)
152. Koohyar Minoo (Motorola Mobility)
153. Marta Mrak (BBC)
154. Janghak Nam (Kwangwoon Univ.)
155. Matthias Narroschke (Panasonic R&D Germany)
156. Tung Nguyen (Fraunhofer HHI)
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