**Joint Collaborative Team on Video Coding (JCT-VC)**
**of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11**
3rd Meeting: Guangzhou, CN, 7-15 October, 2010

Document: JCTVC-C400

*Title:* **Meeting report of the third meeting of the Joint Collaborative Team on Video Coding (JCT-VC), Guangzhou, CN, 7–15 October, 2010**

*Status:* Report Document from Chairs of JCT-VC

*Purpose:* Report

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*Source:* Chairs

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# 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 third meeting during 7-15 October, 2010 at the Guangzhou Baiyun International Convention Center – Oriental International Convention Hotel, in Guangzhou, China. 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 9:00 a.m. on Thursday 7 October. Meeting sessions were held on all days (including weekend days) until the meeting was closed at approximately 1:30 p.m. on Friday 15 October. Approximately 244 people attended the JCT-VC meeting, and approximately 300 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 second JCT-VC meeting in implementing the Test Model under Consideration (TMuC), review results from Tool Experiments (TE), review technical input documents, establish a first Working Draft and HEVC Test Model (HM), and plan a set of Core Experiments (CE) for further investigation of proposed technology.

The JCT-VC produced five important output documents from the meeting: A document describing the process of test model development for HEVC, the HEVC Test Model 1 (HM1), the HEVC specification Working Draft 1 (WD1), a document describing software guidelines and a document providing an overview about the HM1 and WD1 adoptions. Furthermore, 13 documents describing the planning of CEs were drafted.

For the organization and planning of its future work, the JCT-VC established thirteen "Ad Hoc Groups" (AHGs) to progress the work on particular subject areas. The next JCT-VC meetings will be held during 20-28 January 2011 in Daegu, Korea under the auspices of JTC 1/SC 29/WG 11, and during 15-23 March 2011 in Geneva, Switzerland under the auspices of ITU-T Q6/16.

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A new document distribution site http://phenix.it-sudparis.eu/jct/ became operational shortly before the Guangzhou meeting and was exclusively used for distribution of all documents. The new site allows a more automated process of document registration and download. Further improvements are expected in simplified bulk download and particularly for selective download of updated 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 third meeting during 7-15 October, 2010 at the Guangzhou Baiyun International Convention Center – Oriental International Convention Hotel, in Guangzhou, China. 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 9:00 a.m. on Thursday 7 October. Meeting sessions were held on all days (including weekend days) until the meeting was closed at approximately 1:30 p.m. on Friday 15 October. Approximately 244 people attended the JCT-VC meeting, and approximately 300 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://avslab.org/news/mpeg.

## *1.3 Primary goals*

The primary goals of the meeting were to review the work that was performed in the interim period since the second JCT-VC meeting in implementing the Test Model under Consideration (TMuC), review results from Tool Experiments (TE), review technical input documents, and establish a first Working Draft and HEVC Test Model (HM).

## *1.4 Documents*

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/.

The formal deadline for registering and uploading non-administrative contributions was October 1, 2010. Some confusion over document handling occurred as the result of the transition to a new electronic document archive site just prior to the meeting.

Documents with numbers JCTVC-C295 through JCTVC-C320 were all registered after October 2 and uploaded after October 3 (based on the timestamps of the document archive site, which appear to correspond to the local time zone of Paris, France), of which only JCTVC-C296, JCTVC-C297, JCTVC-C299, JCTVC-C301, JCTVC-C302 and JCTVC-C303 were available by the first meeting day. Four of



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these (JCTVC-C310, JCTVC-C317, JCTVC-C319, and JCTVC-C320) were summary reports or side-activity reports generated during the meeting and thus should not necessarily be considered late. The majority of the others were cross-verification reports.

Among the other documents, JCTVC-C030, JCTVC-C068, JCTVC-C114, JCTVC-C165, JCTVC-C174, JCTVC-C175, JCTVC-C178, JCTVC-C179, JCTVC-C180, JCTVC-C181, JCTVC-C182, JCTVC-C225, JCTVC-C231, JCTVC-C244, JCTVC-C247, JCTVC-C248, JCTVC-C287, JCTVC-C288 and JCTVC-C292 had been uploaded after October 3 (based on the timestamps of the document archive site, which appear to correspond to the local time zone of Paris, France), but had been uploaded in some form by the first day of the meeting. Documents JCTVC-C272 and JCTVC-C284 were missing prior to the meeting and were provided by the third meeting day during the meeting. Documents JCTVC-C243, JCTVC-C308, and JCTVC-C309, all of which were cross-verification experiment reports, were only uploaded substantially after the meeting had ended.

Registration timestamps, initial upload timestamps, and final upload timestamps are listed in Annex A of this report. These timestamps reflect activity on the new document site, and some documents had been uploaded (and in some cases, made available for distribution) on the prior document site before being placed on the new document site. The timestamps of the document archive site appear to correspond to the local time zone of Paris, France.

Documents JCTVC-C289, JCTVC-290 and JCTVC-291 were available, but were initially missing an IPR statement.

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. This policy was not strictly enforced at this meeting in a few cases – partly because of the transition to the use of a new document archive site and partly because there were network access difficulties during the meeting – although some late documents were not presented due to lack of time for their presentation. Otherwise, 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.

An issue discussed at the meeting was what to do in the case of a submission of a "placeholder" contribution document that is 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. It was agreed that such submissions do not seem to be constructive, and should be rejected if there is a way to do this in the document handling interface; as such submissions seem to be an attempt to avoid a submission being identified as late while not providing adequate content for study by the participants.

Contribution document registrations JCTVC-C069, JCTVC-C107, JCTVC-C133, JCTVC-C151, JCTVC-C177, JCTVC-C221, JCTVC-C222, JCTVC-C242, and JCTVC-C294 were withdrawn (no documents had been provided, or an incomplete document had been provided, or the registration to JCT-VC had been made in error when intending to submit a document to the WG11 parent body instead).

The report documents of the previous meeting, particularly the meeting report JCTVC-B200, the draft TMuC encoder description JCTVC-B204 and decoder specification JCTVC-B205 were approved. Draft versions 6 and 7 of JCTVC-B205 were made available by Saturday.

## *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.



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## 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 Tool 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, 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)



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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 conducted between JCT-VC and parent body management, as discussed in JCTVC-C001. To proceed on this, JCT-VC issued the following resolution to the WG11 parent body: "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 new site that the group transitioned to using just prior to the meeting. Previously, JCT-VC documents had been made available at http://ftp3.itu.int/av-arch/jctvc-site. The earlier uploaded documents for the meeting were put on the prior site until the transition to using the new site was announced.

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
- **AIS**: Adaptive intra smoothing.
- **ALF**: Adaptive loop filter
- **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).
- **BR**: Bit rate.
- **CABAC**: Context-adaptive binary arithmetic coding.
- **CBF**: Coded block flags.
- **CE**: Core experiment – a coordinated experiment conducted after the 3rd meeting.
- **DT**: Decoding time.
- **ET**: Encoding time.
- **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.



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- **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.
- **MRG**: block merging mode for CUs.
- **MV**: Motion vector.
- **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.
- **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.
- **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**:



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- **CU**: coding unit.
- **LCTU**: largest coding tree unit.
- **PU**: prediction unit.
- **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).
- **WD**: Working draft – the draft HEVC standard corresponding to the HM.

## *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 was summarized and is provided as follows.

- AHG reports and TE summary reports (10)
- TE1: Decoder-side motion derivation (10)
- TE2: IBDI and memory compression (14)
- TE3: Inter prediction (14)
- TE4: Variable length coding (3)
- TE5: Simplified TMuC intra prediction (5)
- TE6: Intra prediction (18)
- TE7: Alternative transforms / MDDT Simplification (19)
- TE8: Parallel entropy coding (10)
- TE9: Large block structures (4)
- TE10: In-loop filtering (20)
- TE11: Motion vector coding (12)
- TE12: Evaluation of TMuC tools (79)
- Project planning and test model establishment (14)
- TMuC settings and common test conditions (4)
- Application-specific topics (4)
- Loop filtering (5)
- Block structures and partitioning (12)
- Motion compensation and interpolation filters (10)
- Motion vector coding (2)
- B picture reference list redundancy (2)
- Quantization control (1)



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- Entropy coding (13)
- Intra prediction (24)
- Transforms and residual coding (10)
- IBDI and memory compression (3)
- Complexity analysis (2)

### *1.12 Video sequence viewing during the meeting*

The following informal viewing sessions were held on Saturday in Room 3410 (4th floor, building 3) during the meeting:

- From 10 am to 2 pm, viewing of TMuC-encoded video with Super High Vision resolution (cropped areas).
- From 2 pm to 5 pm, viewing of in-loop filtering TE video.

In a resolution conveyed to the WG11 parent body, the JCT-VC thanked Prof. Liang Fan of Sun Yat-sen University, Mr. Taichiro Shiodera of Toshiba, and Mr. Kenta Senzaki of NEC for assistance with video viewing experiment during the 3rd meeting of the JCT-VC.

# 2 AHG reports

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

**JCTVC-C001 AHG report: JCT-VC project management [G. J. Sullivan, J.-R. Ohm (co-chairs)] (missing prior, available first day)**

This document reported on the work of the JCT-VC *ad hoc* group on Project Management.

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

One key topic discussed at the management level in the interim period was the need to establish an appropriate copyright status for the test model and reference software being developed by the JCT-VC, as noted in the JCT-VC Terms of Reference. The intent is for the software to be developed as part of the work to develop the HEVC standard and also for it to be published as reference software by ITU-T and ISO/IEC.

In regard to the software copyright issue, it was suggested to conclude as follows:

- That the software copyright management should be established in a manner that protects the patent rights of contributors (which are subject to the ITU-T/ITU-R/ISO/IEC Common Patent Policy) and minimizes any concerns regarding avoiding any other liabilities for contributors and users.
- In particular, it has been expressed that the scope of copyright rights to use of the software should not be substantially constrained.
- The MXM form of the BSD license as quoted above from WG11 N10791 may be a good candidate language to consider, and nearly all of those who have contributed to the software thus far have agreed to allow its use. The only reservation that has been expressed by any contributors regarding the use of the MXM form of the BSD license is a further desire to ensure full clarity that no patent rights are granted by the availability of the software.



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- If the MXM form of the BSD license cannot be used for some reason, an alternative candidate language has been provided herein for consideration.
- As it does not currently seem feasible to immediately establish a particular language declaring the copyright status of the software, it must be understood by all contributors that the JCT-VC and its parent bodies plan to establish such a statement and that the act of contributing to the software involves agreeing to allow the group to do so (in a manner consistent with addressing the concerns stated above to the extent feasible).

These recommendations were reviewed and the intent was agreed. Consideration by the parent bodies was suggested, and the topic was addressed in a resolution produced as an output of the meeting.

**JCTVC-C002 AHG report: Test Model under Consideration (TMuC) editing [K. McCann (chair), M. Karczewicz, J. Ridge, S. Sekiguchi, T. Wedi, T. Wiegand (vice-chairs)] (missing prior, uploaded on first day)**

Following the Geneva meeting, this AHG began the editorial work on the TMuC decoder description using JCTVC-B205 draft000 as the initial draft. This was identical to JCTVC-A205 draft007, the final draft from the Dresden meeting, but with all changes accepted. Seven additional drafts of this output document were produced in the interim period. The last two of these drafts were produced just as the meeting approached, and had not yet been made available for download until after the 3rd meeting began.

There was no initial draft from the Geneva meeting for JCTVC-B204, the corresponding encoding document, which would also provide some tutorial information to explain how TMuC works. Shun-ichi Sekiguchi led the production of this document.

The recommendations of the TMuC Editing AHG were to:

- Approve the edited JCTVC-B204 (TMuC encoder) and JCTVC-B205 (TMuC decoder) documents as JCT-VC outputs
- Continue to edit the TMuC encoder and decoder documents to ensure that all agreed elements of the TMuC are fully described
- Compare the TMuC documents with the TMuC software and resolve any discrepancies that may exist
- Improve the editorial consistency by ensuring that all “normative-style” text is in the decoder document, which may be referred to by the encoder document
- Encourage more people to volunteer to contribute text to the TMuC encoder document
- Consider generating a new pair of documents to describe the future Test Model, assuming that the TMuC continues to exist and evolve in parallel with the Test Model

The further discussion of this report included the following remarks:

- We need to work to resolve any discrepancies between document and software
- There should be no normative phrasing style in the encoder description document (and not an excessive amount of informal informative remarks in the decoder specification either)
- The establishment of a TM may be an opportunity to increase the level of editorial discipline.

**JCTVC-C003 AHG report: Software development and TMuC software technical evaluation [F. Bossen (chair), P. Chen, D. Flynn, W.-J. Han, K. Sühring, H. Schwarz, K. Ugur (vice-chairs)] (missing prior, uploaded during meeting)**

Initially, a non-final draft of this AHG report was discussed. The final report was submitted later during the meeting.



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The activities of the AHG included integration of missing tools into a common code base, resolution of compatibility issues between tools, bug fixes, etc. A near-complete implementation of TMuC had become available.

A brief summary of activities related to each mandate is given below.

- Development of the software was coordinated with the parties needing to integrate changes. Several tracks were typically pursued in parallel to speed up development. The distribution of the software was made through the SVN servers set up at HHI and BBC, as announced on the jct-vc reflector. No documentation was produced at this time.
- Version 0.6 of the software was delivered according to schedule. Due to the presence of a number of known bugs in version 0.6, a version 0.7 was delivered a few days later with a number of fixes and was recommended as the base version to be used for experiments. Reference encodings were generated using version 0.7 by several parties and distributed through an ftp server set up at the BBC.
- As of version 0.8.1, almost all tools included in TMuC had been integrated into a common code base. Missing tools were:
    - Motion vector scaling (Qualcomm). Qualcomm indicated that they no longer wished to proceed with this integration.
    - Geometric partitions (Qualcomm). This tool had been integrated into the 0.8-qualcomm branch but has not yet been merged into a release version of the software.
    - 3-input adaptive loop filter (Panasonic). This tool had been integrated into the 0.8-panasonic branch but had not yet been merged into a release version of the software.
- In addition to these missing tools, the following code contributions had not been merged into a release version of the software due to lack of time:
    - Bug fixes related to the PU-based merging tool which are present in the 0.8-hhi-bugfix branch
    - Unification of PIPE and load balancing which is present in the 0.8-rim-bugfix branch
- A number of additional macros were added to the software to improve its configurability. Requests for new control switches were handled through the public issue tracker set up by the BBC.

Multiple versions of the TMuC software were produced and announced on the jct-vc email reflector. A detailed history of changes made to the software can be viewed at http://hevc.kw.bbc.co.uk/trac/timeline

Released versions of the software are available on the SVN server set up at the following URL: https://hevc.hhi.fraunhofer.de/svn/svn_TMuCSoftware/tags/{version number} where {version number} corresponds to one of the versions described below (e.g., 0.7). Intermediate code submissions can be found on a variety of branches available at https://hevc.hhi.fraunhofer.de/svn/svn_TMuCSoftware/branches/{branch name} where {branch name} corresponds to a branch (e.g., 0.8-qualcomm).

The AhG recommended to the JCT-VC to:

- Use the TMuC software for the development of TM software
- Clean-up the TMuC software to remove parts that are not relevant anymore
- Address remaining critical issues filed on the issue tracker, if any

The discussion of this report included the following remarks:

- Improving configurability is desirable



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- There had been some parallel software development; after which merging was then necessary – David Flynn particularly helped with that.
- Documentation of software configuration was not adequately advanced.
- It is especially important to keep track of intended normative behavior during the software development process, and ensure that normative behavior cannot be changed casually.
- 0.6 version was produced on the planned date, but it did not contain all planned elements (two missing at that time – one not pursued and the other rescheduled a month later).
- Various bugs had been identified within a couple of days and version 0.7 was issued and recommended for use in testing, and was used to generate the common conditions anchors made available on BBC hosted ftp site.
- Some extremely minor platform dependencies were noticed on Win32 systems – possibly compiler optimization (e.g., up to 0.05 dB PSNR differences).
- Some tools were still missing in 0.8.1 (motion vector scaling not pursued, geometric partitions just submitted and not yet merged, 3-input loop filter due to branch divergence issues – now seems to be available).
- Substantial new kinds of configurability were added.
- It is important to identify and preserve the distinction between what should be considered as a new proposal and what is just an improvement of configurability, and what should be considered as a bug fix.
- It is possible to see the software integration timeline in the software tracking system.
- For the "load balancing" aspect in V2V entropy coding, software had been submitted but not yet merged.
- PU-based merging fixes remained to be finalized.

**JCTVC-C004 AHG report: Alternative transforms [R. Cohen, R. Joshi (co-chairs)]**

Discussions for this AHG were carried out over the main JCT-VC reflector (jct-vc@lists.rwth-aachen.de), usually with the term “AHG – Transforms” in the subject line. The discussions were mainly related to how to test alternative transform-related tools in TE12. An example of this was testing of MDDT and ROT. After some discussions, it was agreed to test MDDT and ROT under 3 different conditions, namely, MDDT=0 and ROT=0, MDDT=1 and ROT=0, MDDT=0, ROT=1. There was also some discussion about EDGE_BASED_PREDICTION and MDDT not being combined in an optimal fashion. A related TE (TE7) explored alternatives to the MDDT transform currently in the TMuC. A synopsis of TE7-related contributions was also included in this AHG report. Several cross-verifiers found that that the encoder produced slightly different results depending upon the platform, in part due to known issues with TMuC 0.7.

The contributions related to alternative transforms that had been registered for this meeting were noted.

Tool Experiments TE7 and TE12 related to the work of this AHG, and various contributions had been submitted in relation to these TEs. The AHG report included a summary of TE7 related contributions.

**JCTVC-C005 AHG report: In-loop and post-processing filtering [T. Yamakage (chair), Y. J. Chiu, M. Karczewicz, M. Narroschke (co-chairs)]**

This document summarized the In-loop and post-processing filtering Ad hoc activities between the 2nd JCT-VC meeting in Geneva, Switzerland (21 to 28 July, 2010) and the current 3rd JCT-VC meeting in Guangzhou, China (7 to 15 October, 2010).

There were a few email exchanges for this period. A related TE (TE10) covered most of mandates.



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Other than the work on TE10, there were two contributions JCTVC-C085 and JCTVC-C113 that compared loop and post filtering. Although the examined post filtering methods in JCTVC-C085 may not be the best, the contribution made a comparison (in a fair manner in terms of coding conditions) for three methods. JCTVC-C113 presents experimental results using a different platform (i.e. JMKTA 2.7).

There is also a report of signaling the position of an ALF flag in JCTVC-C084 and some verification results were supposed reported as JCTVC-C243. However, JCTVC-C243 was not uploaded until substantially after the meeting had ended.

The related contributions were reviewed in the AHG report.

Related to Mandate 1, 2, 3 and 4:

TE10 has conducted experiments for three technical categories (deblocking/debanding filters, Wiener-based in-loop filters and Image clipping and offset). A summary of experimental results is reported in JCTVC-C083.

Subtest 2 (Wiener-based in-loop filters) covered the complexity assessment at encoder side as well as coding efficiency assessment. There are complexity related contributions outside of TE10 activities, JCTVC-C113, JCTVC-C086 and its verification JCTVC-C212. In addition, a contribution (JCTVC-C173) proposes a coupled control of deblocking filter and Wiener-based filter, and a contribution JCTVC-C214 for TE12 to study various inputs to Wiener-based filters. There are contributions JCTVC-C195, JCTVC-C219 and JCTVC-C222 to enhance Wiener-based in-loop filtering.

Informal subjective viewing for TE10 was conducted during this meeting.

Related to Mandate 5:

There are two contributions JCTVC-C085 and JCTVC-C113 that compare loop and post filtering. Although the examined post filtering methods in JCTVC-C085 may not be the best, the contribution made a comparison (in a fair manner in terms of coding conditions) for three methods. JCTVC-C113 presents experimental results using a different platform (i.e. JMKTA 2.7).

There was a report of signaling position of ALF_flag JCTVC-C084 and verification results in JCTVC-C243. However, JCTVC-C243 was uploaded substantially after the meeting had ended.

Subjective viewing was conducted at the current meeting for some proposals (in room 3410 on 4th floor of building 3). T. Yamakage assisted in coordinating the scheduling of subjective viewing. It was generally agreed that we should avoid spending substantial time on viewing of cases where no substantial difference in quality will be perceived.

**JCTVC-C006 AHG report: Large block structures [K. Panusopone (chair), M. Budagavi, W.-J. Han, D. He (vice-chairs)] (missing prior, available first day)**

This report summarized the large block structures ad hoc activities between the 2nd JCT-VC meeting in Geneva, Switzerland (21 to 28 July, 2010) and the current 3rd JCT-VC meeting in Guangzhou, China (7 to 15 October, 2010).

There were some discussions relating to this ad hoc group on the main JCT-VC reflector during the interim period. The discussions included reporting of encoder crashes with some CU/PU/TU size combinations, and how to handle these issues. For example, the horizontal padding and vertical padding (or --PAD option) should be used to ensure that both frame width and height are a multiple of LCTU. There were also a lot of activities relating to large block structure occurred in TE 9 and TE 12; namely, Unit Defintions tests in TE 12 and performance tests for different CTB and TU sizes in TE 9.

There are some input documents proposing solutions either to handle boundary issues, to allow flexible block partitioning, or to improve signaling efficiency. Additionally, TE 9 activities related to the mandates of this AHG. There also had been some initial discussions with the AhG on in-loop and post-processing filtering for a potential collaboration on evaluating performance of the current ALF filtering control information at the CU level.



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**JCTVC-C007 AHG report: Memory compression [K. Chono (chair), T. Chujoh, C. S. Lim (vice-chairs)]**

The ad hoc group (AHG) on memory compression was formed during the July 2010 JCT VC meeting in Geneva. The bulk of this AHG activity has been devoted to discuss and develop an MC read memory access bandwidth measure module for TMuC software in order to access the results of TE2: IBDI and Memory Compression. Approximately 70 e-mail messages were exchanged between the members from 4 parties/companies.

The following items are listed as the benefits of memory compression for video encoders and decoders:

- Reduction in MC read memory access bandwidth;
- Reduction in DPB write memory access bandwidth; and
- Graceful power degradation by enabling the low resolution decoding of a bit-stream.

The second item can be reasonably assessed by comparing the compression ratios of memory compression schemes since the DPB write memory access is not random access. Similarly, the third item can be reasonably assessed by counting the number of low resolution samples. Therefore, AHG activity has been devoted to discussing the first item. Indeed, it was mentioned by JCT-VC chairs during the last JCV-VC meeting that the compression ratios of memory compression schemes are not a comparable measure since overheads that come from the overlaps of the size of memory compression unit access in MC read random access are unclear.

Through the discussion on the first item as described in detail below, the AHG developed a module that computes run-time memory access bandwidth measure for TMuC decoder.

In order to have a comparable measure, some TE2 members suggested developing a module that computes run-time memory access bandwidth for given the combination of MC block size, the tap-length of MC interpolation filter, Motion Vector (MV), sample-bits per pixel, etc. AHG members agreed to the suggestion and discussed a YUV storage structure in reference picture buffer. By considering the TMuC design in which the same MC interpolation filter is applied to UV components and a different MC interpolation filter is applied to Y component than UV's, the member decided to employ a YUV format comprising of a plane Y component and horizontally-interleaved UV components.

AHG members developed the module and updated it to account for the overlaps of a memory compression unit size. Given a combination of MC block size, the tap-length of MC interpolation filter, MV, sample-bits per pixel, memory compression unit size, the updated module computes the memory access samples.

Then AHG members discussed a model of compressed reference storage and decided to use a 1-D storage model. In the 1-D storage model, a memory compressor compresses each of compression units and stores its compressed versions, whose size is byte-aligned, into 1-D storage in the raster scan order. A memory decompressor accesses a set of compressed reference data units stored in the 1-D storage and outputs the decompressed compression units (MC reference samples) to a MC module. Since the 1-D storage access is restricted by memory alignment and memory burst sizes, the actual memory access size (referred to as run-time memory access bandwidth) is determined on the basis of the associated memory read overheads as well as the number of compressed reference data units.

Although run-time memory access bandwidth is varied by memory allocation methods, AHG members agreed that the raster scan is used as a default setting and that TE2 proponents can report run-time memory access bandwidth measures obtained by their specific memory allocation methods in addition to those obtained by the default setting. The reason is that the optimal memory allocation method depends on a memory compression unit size as well as memory alignment and memory burst sizes.

After having the 1-D storage model, NEC offered their resources to implement the module and to integrate it into the top of TMuC0.7 decoder. The module can be turn on and off by setting a macro "#define MC_MEMORY_ACCESS_CALC 1" in TypeDef.h. Panasonic and TI inspected it prior to the module distribution to TE2 participants. (Note that current implementation supports the runtime memory



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access only for Anchor encoding settings, i.e., SIFO with 12tap and AMV res., and DIF without AMV res. Furthermore there are two restrictions: for a SIFO with 12tap and AMV res. case, the number of tap-lengths is not switched as the TMuC document specifies; for a DIF case, the shapes of memory access on diagonal fractional pixel positions are assumed to be rectangular. However, the above restrictions presumably do not affect the assessment of MC read memory access bandwidth reduction obtained by memory compression schemes since Anchor and Proposal MC read memory access bandwidths are computed by the same way.)

A template excel sheet containing the memory access bandwidth measurement of the anchor streams generated based on JCTVC-B300.doc was created and distributed to TE2 participants along with the software. Using the module created by NEC, the total MC read memory bandwidth of the anchor streams for high efficiency and low complexity settings are computed based on combinations of DDR address and burst alignment bits, (8,8), (32, 64), (64, 128), (128,128), and (256, 256). Using the same memory bandwidth computation tool provided by NEC, the TE2 participants were requested to provide the total MC read memory bandwidth measurement of the same anchor streams based on each proponent's proposed memory compression unit size and compression ratio.

It was also discussed that having a simple cache model to measure memory bandwidth after the use of cache will be desirable since many video coding solutions in the marketplace use cache memory. Video coding solutions that do not use cache are also widely used in the marketplace, so the cache model needs to have the option of being switched on and off. TI offered their resources to implement a simple cache model on top of NEC's memory bandwidth measurement module in TMuC0.7 decoder. After a quick informal survey of existing L1 and L2 cache architectures on recent microprocessors and DSPs, a single level cache with following parameters was implemented in TMuC-0.7 decoder with capacity (cache size): 128 KB, line size: 64 bytes, organization: 4-way set-associative, replacement strategy: FIFO (a least Recently Used (LRU) strategy is industry standard, but FIFO is easier to implement), DDR alignment: 64 bits. The aim of the cache model is to have a simple cache simulation that captures the most relevant parameters for comparing bandwidth consumed, with and without memory compression, and that is fair to all block structures used in memory compression. The goal was not to develop a very sophisticated cache model. The software cache model was released TE2 members after it was inspected by NEC and others.

The memory bandwidth usage is printed in the same format used by NEC's memory bandwidth measurement module. The code changes are isolated to be in #if MC_MEMORY_ACCESS_CACHE. MC_MEMORY_ACCESS_CALC needs to be enabled before cache can be used.

It was noted that lossless aspects of memory compression (e.g entropy coding) may not need to be standardized.

The recommendations of the AHG were to:

- Adopt the developed run-time memory access modules to the main branch of the software with a macro to be turned on or off by compilation
- Study MC memory access bandwidths of the combination of different minimum inter PU partition sizes and several TMuC MC interpolation schemes
- Study essential functionalities of memory compression schemes that need to be standardized in order to keep the interoperability of encoders and decoders

In the discussion of the report, it was remarked that there may potentially be subjective impairments associated with memory compression that should be considered.

It was suggested that a reduction of memory access bandwidth on the order of 50% may be a realistic goal.



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**JCTVC-C008 AHG report: Parallel entropy coding [M. Budagavi, A. Segall (co-chairs)] (missing prior, available first day)**

Parallel entropy coding tools were proposed in several contributions at the April 2010 JCTVC meeting in response to HEVC CfP. The parallelism proposed in those contributions can be broadly classified into three categories:

- Bin-level parallelism, which parallelizes the binary arithmetic coder (BAC), as in:
    - N-bin BAC in JCTVC-A101
    - PIPE/V2V in JCTVC-A116 and JCTVC-A120
- Syntax element-level parallelism, which parallelizes the BAC, the context modeler, and the binarizer, as found in syntax element partitioning JCTVC-A101.
- Slice-level parallelism, as in:
    - Entropy slices, JCTVC-A105
    - Interleaved entropy slices, JCTVC-A101
    - Sub-streams coding, JCTVC-A114

In the July JCTVC meeting, context processing was identified as an additional bottleneck. The following context parallelization tools were proposed in the July meeting and a Tool Experiment TE8 was established to further study this is more detail.

- Parallel context processing (PCP)
    - Coefficient Sign PCP (JCTVC-B088 Section 3.2)
    - Coeff Level BinIdx 0 PCP (JCTVC-B088 Section 3.3)
    - Significance map PCP (JCTVC-B088 Section 3.4)
    - Coding order for significance map on bin decoding throughput (JCTVC B036 Section 2)

Results on entropy slices were also presented in the July JCTVC meeting, as in entropy slices for parallel entropy coding (JCTVC-B111).

There was no email activity related to this AhG on the JCTVC reflector. However, several AhG members interested in this area were actively participating in proposal/cross-verification of parallel entropy coding within TE8 and TE12.

Thirteen related contributions were noted.

The AhG recommended to review all relevant input contributions.

A question that was discussed was how to measure the amount of parallelism that is achieved. There are some metrics that have been proposed in contributions, and we should study these to determine their acceptability.

**JCTVC-C009 AHG report: Screen content coding [J. Xu, W. Ding (co-chairs)] (missing prior, uploaded first meeting day)**

The document summarized the activities of the screen content coding AHG between the 2nd and the 3rd JCT-VC meetings. The mandates of the AHG were to identify and describe use case scenarios including non-camera-view content; investigate and collect appropriate test material including computer screen captures, mixed video and graphics, animated graphics, game content, CAD video, news content, text overlays, etc.; and identify potential needs for action in HEVC standardization. There was very little activity for this AHG during the interim period, and only one related input document was submitted for the 2rd meeting (JCTVC-C276).



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The topic was discussed and further input was encouraged. MPEG and VCEG also discussed the topic at their co-located meetings. To further progress on this, JCT-VC issued the following resolution to WG11: "The JCT-VC has received input contributions that indicate a potential need to consider the coding of "screen content" (text and graphics mixed into a video source, computer desktop or mobile device display content, scrolling text over video, etc.), which may have different characteristics than the camera-captured content as used in the HEVC CfP. NBs are requested to comment about the relevance of such content to the development of the HEVC standard."

**JCTVC-C010 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 2nd JCT-VC meeting held in Geneva in July 2010 and the current meeting in Guangzhou.

There was moderate activity on the e-mail reflector related to Complexity Assessment since the July meeting. A total of 18 e-mails on the subject were exchanged.

- It had been pointed out that the concept of "complexity" still lacks a fully satisfactory definition.
- It had been suggested that computational complexity could be assessed by measuring the CPU clock cycles using the "rdtsc" instruction, but there was no consensus on the reliability of this kind of measure.
- It had been suggested to use profile tools, e.g. Vtune or oprofile, although no results had been proposed so far.
- Some simulation results showed a discrepancy between computational complexity measures obtained with the TMuC 0.7 decoder on Linux machines and those from a Windows XP machine running Cygwin. The reason for that had not been determined yet.

Several Tool Experiments ran between the last meeting and the current meeting that were aimed at providing both coding efficiency and complexity measurement results. The AHG recommended the JCT-VC experts to review the complexity results considering possible issues with precision, accuracy and reproducibility on different systems.

The AHG encouraged further simulation experiments and discussions among JCT-VC experts toward reaching a consensus on suitable complexity definitions and methods to measure it.

# 3 TE1: Decoder-side motion vector derivation

**JCTVC-C115 TE1: Summary report of TE1 activity [Y.-J. Chiu (Intel), Y.-W. Huang (MediaTek), M. Wien (RWTH Aachen Univ.), H. Yu (Huawei)]**

This contribution summarized the results and various contributions relating to TE1. The contributions and results in this area are further discussed below in this section.

**JCTVC-C097 TE1: Huawei report on DMVD improvements in TMuC [M. Yang, S. Lin, D. Wang, J. Zhou, H. Yu (Huawei)]**

The goal of this Tool Experiment (TE1) was to measure the performance of Decoder-side Motion Vector Derivation (DMVD) techniques in TMuC software. There are two categories in the TE1, one is TE.1a (DMVD Inter Prediction) and the other is TE.1b (DMVD Direct Mode). This contribution continued the work on the Template Matching based DMVD (TM-DMVD) and Spatial and Temporal Direct Mode (STDM) techniques. STDM and TM-DMVD work together in the TE.1a, and STDM works alone in the TE.1b. Both techniques had been implemented into the TMuC 0.7 software and tested following the common test conditions in JCTVC-B300 and JCTVC-B301. This document described these techniques in detail, which included algorithm description, software implementation, coding performance, and complexity evaluation and analysis. According to the test results, the average bit rate savings for the



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random access and low delay configurations were 3.90% and 2.43%, respectively in TE1.a, and 2.9% and 0.5%, respectively in TE1.b.

It was noted that some of the tests for Class A and Class B sequences in the TE1.a random access configuration were not finished yet, and the authors indicated that final results would be updated when these became available. As of the time of writing this report, the latest uploaded version of the contribution still said that the results were not yet finished.

TE1.a

- Results for Random Access were not finished yet when reviewed
- Current decoder runtime increase to 230% for RA, 300% for LD.
- "low complexity" method presented by last meeting not implemented in TMuC yet – estimate to bring complexity increase to 160%.

TE1.b

- Current decoder runtime increase to 118% for RA, 129% for LD.
- Encoder runtime increase negligible
- AMVP was disabled in all TE1

**JCTVC-C128 TE1: Cross-checking of DMVD result from Huawei [Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)]**

This contribution was a cross check of the results of JCTVC-C097 on TE1.a, reporting matching results as far as the results that were available.

**JCTVC-C125 TE1: Spatio-temporal direct mode [S. Sekiguchi, Y. Itani (Mitsubishi Electric)]**

This contribution was a cross check of the results of JCTVC-C097 on TE1.b, reporting matching results.

**JCTVC-C138 TE1.a: Implementation report of refinement motion compensation using DMVD on TMuC [M. Ueda (JVC)]**

In TE1 activity, the tool experiment targets at exploring the performance and value of Decoder-side Motion Vector Derivation (DMVD) and at analyzing the interaction of DMVD with other tools under consideration for HEVC.

This proposal focused on the tool "Refinement Motion Compensation (RMC) using DMVD" which belongs to TE1.a: DMVD Inter Prediction. The feature in RMC is that bi-predictive MC blocks can be obtained by transmitting only one motion vector using inter-reference DMVD.

In this contribution, the implementation of the basic RMC tool on TMuC0.7 software and result of evaluating the performance were reported. The simulation results reportedly showed that the proposed technique provides 1.8% BD-rate gain for the random access case and 0.0% for the low delay case as tested against the TE1 common anchor under TE1 test conditions.

- Decoder runtime increased to 138%, encoder runtime to 146% for RA case
- The method seems not to be working for bi-predictive extrapolation currently
- Results were relative to TMuC anchors without AMVP

**JCTVC-C266 TE1: Cross-check result of DMVD proposal from JCTVC-C138 (JVC/Kenwood) [W.-J. Chien, P. Chen, M. Karczewicz (Qualcomm)]**

The results of JCTVC-C138 were reportedly confirmed in terms of coding performance and speed.



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**JCTVC-C124 TE1: Implicit direct vector derivation [Y. Itani, S. Sekiguchi (Mitsubishi Electric)]**

This contribution reported results of performance verification on implicit direct vector derivation technique that was approved as a part of TE1 at the last (Geneva) meeting. The evaluated technique provides a new design of B-skip and B-direct modes with locally adaptive direct MV derivation relying on a decoder-side decision. A performance evaluation using TMuC software was conducted according to the test conditions defined in TE1, and the results reportedly showed 1.8% coding gain on average for RA case (and up to 3.5% at maximum gain). The increase of decoding time was about 10% relative to the TE1 anchor, and the encoding time was reportedly almost same as that of the anchor. This contribution also provided notes on normative text in the form of modification of the TMuC specification.

- For LD case, 0.4% BR reduction on average
- Decoder time increases 13% for RA case and 5% for LC case; no significant increase in encoder run time
- Comparison against anchors without motion vector competition and without CU merging (skip/direct on)

**JCTVC-C024 TE1: Cross-check result of DMVD proposal JCTVC-C124 (Mitsubishi) [T. Yokoyama, K. Nakamura (Hitachi)]**

This contribution confirmed the results of JCTVC-C124 w.r.t. performance and encoding/decoding time.

**JCTVC-C127 TE1: Report of self derivation of motion estimation improvement in TMuC [Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)]**

This contribution presented the techniques of decoder-side motion vector derivation (DMVD) side to increase the coding efficiency of B pictures. With the motion vector (MV) information self derived at the video decoder side, the transmission of these MVs from the video encoder side to the video decoder side is skipped. The proposed self derivation of motion estimation (SDME) techniques were reported to be friendly to parallel implementation by utilizing on the temporal correlation among the available samples in the previously-decoded reference pictures, instead of operating on the previously reconstructed samples of the neighboring area of the current picture, which poses an inherent decoding ordering causal relationship among decoding blocks of current picture. Experiments reportedly demonstrated an overall 4.8% BD bit rate improvement for the test of random access (high efficiency) category under the TE1 test conditions with 73% increase in encoding time and 150% increase in decoding time increase on TMuC 0.7 Reference Software platform. A fast version of the direct-candidate simplified SDME reportedly demonstrated an overall 3.1% BD bit rate improvement with a 26% reduction in encoding time and 18% increase in decoding time when compared to the TE1 anchor. Another version of the rounded-candidate simplified SDME had reportedly demonstrated an overall 3.7% BD bit rate improvement with 10% increase in encoding time and 13% increase in decoding time when compared to the TE1 anchor. Also, the proposed SDME reportedly demonstrated 2.7% BD bit rate improvement over the anchor of TE12 under the random access test category (high efficiency) on a shorter version of the common test video sequences defined for TE12. A description of the normative syntax change in the form of TMuC specification was included.

In the discussion, it was remarked that the reduction of encoding time is not specific to DMVD, but could be achieved similarly by appropriate encoder optimization (avoid unnecessary checking of intra modes).

**JCTVC-C098 TE1: Cross-checking of DMVD results from Mitsubishi and Intel [S. Lin, D. Wang, M. Yang, H. Yu (Huawei)]**

The results of JCTVC-C124 w.r.t. performance and encoding/decoding time were reportedly confirmed.

The results of JCTVC-C127 w.r.t. performance and encoding/decoding time (x-check for the fast modes not done) were reportedly confirmed.



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**TE1 summary discussion**

Aspects remarked upon in the discussion of TE1 included the following:

- Current TE1 settings were with AMVP (motion competition) off and CU merging off.
- Gains were reported of 4.8% BR reduction average.
- New methods were proposed with significantly less decoder complexity than before.
- Results should be compared against the default TMuC settings (which probably brings the gains down by 2-2.5%).
- Some of the methods seem to reach a region of more moderate increase in decoding complexity.

It was suggested to continue investigation and experiment work on this topic.

# 4 TE2: IBDI and memory compression

## *4.1 Summary*

**JCTVC-C076 TE2: Summary of TE2 on IBDI and memory compression [T. Chujoh (TE coordinator)]**

This contribution is a summary of activies and results relating to tool experiment 2: IBDI and memory compression as described in JCTVC-B302r2. Nine companies and one university had been registered in TE2 and four proposed tools had been evaluated on the common condition with cross-verification. There are two test conditions. One is the case of keeping the bit depth of reference memory to the input bit depth on IBDI and the other is the case of reduction of reference memory access bandwidth and size.

A substantial amount of information was in this summary report.

The proposed techniques were summarized as shown in the table below:

| Tool | Proponent | Cross-checker | Method |
|---|---|---|---|
| 1 | NEC | Panasonic, JVC | DPCM of 8 samples |
| 2 | Panasonic | TOSHIBA | Hadamard transform and bit-plane coding |
| 3 | TI | TOSHIBA | Wavelet transform and DC prediction by 8x8 block |
| 4 | TOSHIBA | NEC, Yonsei Unv. | Adaptive scaling by 4x4 block and de-scaling by sample |

The summary report included tables illustrating the impact on measures relating to coding efficiency, complexity, and memory access for HE and LC configurations

It was remarked that for the various memory compression schemes in general, the behavior on static regions may be a particular concern.

It was also noted that more complex techniques need to be significantly better than 8 bit rounding of IBDI results in order to to be useful.

## *4.2 1-D DPCM-based memory compression*

**JCTVC-C093 TE2: 1-D DPCM-based memory compression [H. Aoki, K. Chono, K. Senzaki, J. Tajime, Y. Senda (NEC)]**

In this contribution, a performance report on the 1-D DPCM-based memory compression method described in JCTVC-B057 was presented. The method was designed to reduce reference frame memory size and memory access bandwidth for motion compensation, with relatively low complexity. The method



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employs 1-D DPCM. Experimental results reportedly showed that average coding losses are 10.7% for test cases without IBDI and 2.0% for test cases with 12-bit IBDI. Subjective quality degradation caused by such coding loss was reported to be invisible for most test cases. Average increase of decoding time is as small as 3.0% and memory bandwidth reduction ratios are 40.6% for test cases without IBDI and 49.0% for test cases with 12-bit IBDI. Experimental results on bandwidth reportedly showed that bandwidth reduction depends on memory architecture and implementation on mapping of compressed image data onto frame memory.

It was remarked that the 2% loss with IBDI seems to be most of the gain that IBDI provides.

It was remarked that such a proposal should be compared against just rounding to 8 bits when storing.

JCTVC-C094 and JCTVC-C095 are related proposal documents for a new proposal.

It was asked whether the decoder is required to do clipping after reconstruction of each sample. The proponent indicated that this is not necessary. Instead, the encoder must perform quantization in a way that avoids reconstruction overflow.

**JCTVC-C074 TE2: Cross-check of memory compression results from NEC (JCTVC-B057/JCTVC-C093) [C. S. Lim, V. Wahadaniah, S. Naing, H. W. Sun (Panasonic)] (had been uploaded on the ITU ftp site and was only later put on the new site)**

The purpose of this document was to present a cross-check of memory compression results from NEC (JCTVC-B057/JCTVC-C093) for Tool Experiment 2 (IBDI and memory compression). The cross-check was reportedly completed successfully and the results from NEC were reportedly reproduced without any problem.

## *4.3 Reference frame compression using image coder*

**JCTVC-C073 TE2: Reference frame compression using image coder [C. S. Lim, V. Wahadaniah, S. Naing, H. W. Sun (Panasonic)]**

This contribution presented results of Tool Experiment 2 (IBDI and memory compression) from the reference frame compression scheme proposed by Panasonic (JCTVC-B103). The presented reference frame compression scheme uses an image coder comprising a transform, scanning, and bit-plane coding. The presented scheme was implemented on TMuC version 0.7.3 revision 188 and experiments were conducted using the common test conditions defined in the Tool Experiment 2 document (JCTVC-B302).

The memory compression rate used in the experiments for High Efficiency setting was 12-bit to 5.33-bit (44.4%). In comparison with the TMuC software without reference frame compression, experiment results reportedly show an average coding efficiency drop of 2.9% for the High Efficiency, Random Access setting and an average coding efficiency drop of 4.7% for the High Efficiency, Low Delay setting.

The memory compression rate used in the experiments for Low Complexity setting was 8-bit to 5.33-bit (66.7%). In comparison with the TMuC software without reference frame compression, experiment results reportedly show an average coding efficiency drop of 2.9% for the Low Complexity, Random Access setting and an average coding efficiency drop of 4.0% for the Low Complexity, Low Delay setting. It was noted from the results in all test settings that the larger drop in performance occurs in the lower resolution images.

It was remarked that the complexity of the proposed reference frame compression method seems relatively high, and the coding efficiency impact is not negligible.

**JCTVC-C178 TE2: Cross-check of memory compression results from Panasonic (JCTVC-C074) [A. Segall (Sharp)] (missing prior, available first day)**

This contribution provided a cross-check of memory compression as proposed by NEC and results provided by Panasonic. This cross-check was performed within the context of TE2. The experimental results reportedly closely matched the rate-distortion results provided by Panasonic. The reported



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maximum Y BD Rate differed from the provided results by at most 0.1%. The cross-checker indicated that he had read through the software and found it to match the proposal algorithm.

## *4.4 TI reference frame compression proposal*

**JCTVC-C060 TE2: TI reference frame compression proposal [M. Zhou, M. Budagavi (TI)] (late IPR declaration prior)**

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-0.7 reference software and tested with the JCT-VC common testing conditions. For the High Efficiency (HE) configurations in which IBDI was enabled, the proposed algorithm reportedly provided 12 bits to 8 bits compression at the cost of an average BD-rate increase of 0.3% for random access configurations and 1.7% for low-delay configurations, respectively. The average motion compensation memory bandwidth was reportedly reduced by amounts ranging from 14.7% to 45.7%. For the low complexity (LC) configurations in which the IBDI is off, the proposed algorithm provided 8 bits to 4 bits compression, with a reported average BD-rate increase of 2.5% for random access LC and 3.4% for low-delay LC, respectively. The memory bandwidth saving is 50% if the growing window is employed.

A cross check was reportedly done by Toshiba, but no document was submitted for that, other than a summary in JCTVC-C076.

Further study was encouraged.

## *4.5 Adaptive scaling for bit depth compression on IBDI*

**JCTVC-C075 TE2: Adaptive scaling for bit depth compression on IBDI [T. Chujoh, T. Yamakage (Toshiba)]**

In this contribution, results of an adaptive scaling for bit depth compression on IBDI were reported. This was one of the proposals in Tool Experiment 2 on IBDI and memory compression. The purpose of this tool experiment was to improve coding efficiency by increasing internal process of video codec while minimizing reference frame memory access bandwidth and reducing reference frame memory access bandwidth and reference frame memory size. This contribution reported an average 0.8% loss for bit depth compression on IBDI.

By design, it was reported that the method should provide a benefit relative to fixed rounding.

There was reportedly a substantial impact of fixed rounding to 8 bits for the Class E sequences.

A substantial memory access bandwidth reduction was reported.

It was remarked that performance may depend on the applied QP / fidelity.

Another proposal JCTVC-C077 also related to this, as described elsewhere in this report.

**JCTVC-C150 TE2: Cross-check of memory compression results from TOSHIBA (JCTVC-C075) [Y. Choe, S. Hong (Yonsei Univ.), Y-G. Kim (KGIT)]**

This document reported cross-checking results of adaptive scaling of bit depth compression for IBDI (Internal Bit Depth Increase) coding, which was proposed by Toshiba as described in JCTVC-C075. The proposal was evaluated based on the TMuC 0.7 with BUGFIX50TMP software and configuration files which were based on JCTVC-B302r1. The software package was obtained from Toshiba.

The verification was reported to have been carried out by encoding the test sequences and decoding the generated bitstreams, collecting PSNR/bit rate numbers and encoding/decoding times and verifying that the numbers generated matched those in the proponent's spreadsheets.



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The results were reported to be consistent with the data provided by Toshiba. The contribution did not indicate whether the algorithm or software were carefully studied.

### *4.6 Summary conclusions on TE2*

It was agreed that further study of the techniques involved in TE2 was desirable. However, it was agreed not to include these proposed techniques in the test model.

# 5 TE3: Inter prediction

**JCTVC-C220 TE3: Summary report for inter prediction in HEVC [A. Krutz, T. Sikora (Tech. Univ. Berlin)]**

This document summarized the interim activity relating to TE3 – Inter prediction in HEVC (JCTVC-B303). The TE was separated into four subtests that were Subtest 1 – Warped motion compensated and second order prediction, Subtest 2 – Flexible motion partitioning, Subtest 3 – Multi hypothesis inter prediction, and Subtest 4 – Improved inter prediction with enhanced MC filter. The results that had been generated prior to the writing of this document were summarized. Due to the short period of time, integration in the new software and running the experiments was reportedly a big task. Therefore, not all participants who intended to actively contribute to this TE at the last meeting had shown results for their proposed tools.

**JCTVC-C033 TE3: Motion compensation with adaptive warped reference [S. Park, J. Park, B. Jeon (LG Electronics)]**

This document presented experimental results of TE3 subtest 1, which aimed to improve temporal prediction performance by using warping motion. This tool uses an additional reference picture which is warped version of the original reference picture based on homography relation between the current picture and the reference picture. Using a test set different than the typical common conditions, the experimental results reportedly showed 3.1% overall bit rate savings under 'low delay & high efficiency' condition and 3.5% overall bit rate savings under the 'random access & high efficiency' condition as compared with TMuC 0.7.3.

The results were achieved by adding additional sequences into the common test set. Using only the test set would have resulted in very small measured gain or even loss. The highest gain for the TS was Cactus, 3.1% BR savings. The maximum gain reported gain was for "station 2" LD at 41.1%.

The following remarks and observations were made in the discussion of this contribution:

- Sequences that are added usually do not have much texture and are easy to code.
- With the current results there may be no reason to take action. The sequences where gain is shown are mostly easy to code (blur, low amount of texture) and were not selected as group test sequences before because of this reason.
- Further study is recommended, but more evidence should be shown with appropriate test material.

**JCTVC-C282 TE3 subtest 1: Cross-check of results from LG [M. Tok, A. Glantz, A. Krutz, T. Sikora (Tech. Univ. Berlin)]**

The purpose of this document was to cross-check JCTVC-C033 on motion compensation with adaptive warped reference picture as submitted by LG Electronics. The verification task was reported to have been done successfully, with results that matched those proposed in JCTVC-C033.

A verification of the source code had not been done. LG Electronics had provided Windows 64 binary executable files and encoded bitstreams for the cross check activity.

This sort of "black box" testing does not appear to be a satisfactory cross-check for JCT-VC purposes.



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**JCTVC-C031 TE3 subtest 2: Report on simplified geometry block partitioning [E. Francois, D. Thoreau, P. Bordes (Technicolor), L. Guillo (INRIA)]**

This document relates to TE3 subset2 "flexible block partitioning". It reported results of Simplified Geometry adaptive block partitioning (SGEO) as proposed initially in document JCTVC-B085. The reported BD-rate results were as follows. Compared to the TE03 reference, SGEO average Y BD-rate gainswere, respectively, 3.1% for Random Access High Efficiency, and 2.9% for Low Delay High Efficiency. Compared to GEO, SGEO average BD-rate loss is less than 1% for both Random Access High Efficiency and Low Delay High Efficiency. SGEO average encoding time reduction was reported to be around 20-25% compared to GEO. The decoding time was reported to not be significantly impacted.

The following remarks and observations were made regarding this contribution:

- Current implementation does not support CU merge
- Encoding time was reported to be around 300% compared to the case of TMuC reference with AMP off with SGEO.
- The 4% gain appears attractive, but the current complexity is too high.

**JCTVC-C170 TE3.2: Report on cross-verification of simplified geometry block partitioning from Technicolor [X. Zheng (HiSilicon), H. Yu (Huawei)]**

This contribution confirmed the results of JCTVC-C031 to the extent of the cross-check testing that was reported (all of class D were said to have been completed and some other sequences). Only very minute differences were reported, likely due to platform compiler issues. It was reported that the data of Technicolor's proposal were matched with the cross-verification data. For random_access case, when turning off MRG for the anchor, the ratio of encoding time between Technicolor's proposal and anchor decrease from 3.2 times to 2.8 times, while the BD-rate saving has slight decrease. For low delay case, when turning off MRG for anchor, the ratio of encoding time between Technicolor's proposal and the anchor decreased from 2.8 times to 2.6 times, while BD-rate saving had slight increase.

**JCTVC-C099 TE3.2: Huawei & HiSilicon report on flexible motion partitioning coding [X. Zheng (HiSilicon), H. Yu (Huawei)]**

This contribution reported Huawei & HiSilicon's implementation status of flexible motion partitioning on the TMuC platform. Based on the test results achieved so far, the proposed partitioning method can reportedly bring about 1.6% bit rate saving over the TE3.2 anchor for random access high efficiency configuration, and 2% bit rate saving for low delay high efficiency configuration compared against anchors with AMP off. The coding performance can reportedly be further improved with the addition of more flexible partitioning cases.

The following remarks and observations were noted in discussion:

- Encoding time compared to TMuC default with AMP off increased to about 200%.
- The current complexity is too high. This needs to be further studied.
- Subjective effects should be studied.

**JCTVC-C034 TE3 subtest 2: Cross-check of results from Huawei [E. Francois, P. Bordes (Technicolor)]**

The purpose of this document was to report cross-checking of the Flexible Block Partitioning tool proposed by Huawei/Hisilicon for TE03 subset 2. The source code had been analyzed and the conformance of the code with the tool description had been verified. The source code had been compiled successfully using Windows32 with VC 2005. The verification task had reportedly been done successfully and the results matched those presented in JCTVC-C099.



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The cross-check of JCTVC-C099 was performed for classes C, D and E. Results were confirmed with minor mismatches (due to different platforms).

Regarding encoding and decoding time comparisons, the test had also been performed on a limited set of cases. The time ratios between FMPHV encoding and default TMuC encoding measured were approximately of 140-150% for both Random Access and Low Delay cases. The time ratios between FMPHV encoding and "TmuC without AMP" encoding measured were approximately of 230-240% for both Random Access and Low Delay cases. Decoding time was almost not impacted.

**JCTVC-C236 Report of complexity analysis of geometric partitioning [K. Vermeirsch, J. De Cock, R. Van de Walle (Ghent Univ. - IBBT)]**

This contribution was a report on a complexity analysis which was carried out at the Multimedia Lab of Ghent University. In this analysis a geometric partition mode is defined in function of a partition boundary line having a certain orientation (angle) and offset from the block center. First, the complexity and compression gains of geometric partitioning were determined as a function of the number of allowed orientations. Secondly, the analysis investigated the histograms of the location of the partition boundary within blocks w.r.t. the block center. Based on these observations, a strategy for complexity reduction can reportedly be put forward. By only testing a subset of partition modes, the complexity can reportedly be reduced by a factor of 40 while retaining over 50% of the gains of the more exhaustive approach.

The contribution was considered useful to give hints in reducing encoder complexity in geometric partitioning.

**JCTVC-C233 TE3 subtest 3: Local intensity compensation (LIC) for inter prediction [N. Sprljan, S. Paschalakis, P. Wu (Mitsubishi Electric)]**

This contribution presented the status of implementation of the Local Intensity Compensation (LIC) tool, as a successor to the previously reported Macroblock Weighted Prediction (MBWP), in TMuC 0.7.1. Intensity compensation is done in a form of a locally adapted weighted prediction where parameters are selected for partitions within a prediction unit. The implementation had only been completed partially, and the work on its additional features and fine tuning was ongoing. Although the first results with low complexity configurations show loss of up to 0.7%, it was also observed that LIC can be beneficial for some sequences. This document also described future work which addresses improvements to this method.

The contribution was noted – further study of this technique is needed to reach a conclusion about it.

**JCTVC-C240 TE3: Cross-check results of local intensity compensation tool from Mitsubishi Electric [D. Karwowski (Poznan Univ. Tech.)]**

The contribution presented experimental results on coding efficiency and computational complexity for the Local Intensity Compensation (LIC) tool proposed by Mitsubishi Electric. Experiments were done in the context of Subtest 3: Multi-hypothesis inter prediction defined in Tool Experiment 3: Inter Prediction in HEVC. The aim of the experiments was to cross check the results obtained by authors of the method (Mitsubishi Electric).

When reviewed, no presenter was available for this document – it was reviewed and seemed to confirm results of JCTVC-C233.

**JCTVC-C078 TE3 subtest 4: High accuracy interpolation filter (HAIF) [T. Chujoh, K. Kanou, T. Yamakage (Toshiba)]**

In this contribution, experimental results of high accuracy interpolation filters were reported. This was one of the proposals in subtest 4 of tool experiment 3 on inter prediction. The purpose of this tool experiment was to improve the performance of inter prediction with enhanced motion compensation filters. The experimental results reportedly showed that the interpolation filter which derives each fractional sample position directly and has more steep frequency characteristics with a long tap length can



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achieve good performance, and the interpolation filter and the in-loop filter have strong relationship as a filter processing technology. At the nest stage, computational reduction for the interpolation filter should be discussed in this subtest.

The following remarks were made:

- Uses an asymmetric 6-tap filter for ¼ and ¾ positions, and an 8-tap filter for ½ positions and boundaries.
- This also shows again the dependency of interpolation filter type and ALF gains.
- Complexity investigation not fully conclusive, e.g. 6/8 filter in some cases has longer runtime than 8-tap filter.
- Further study is needed.

**JCTVC-C165 TE3 subset 4: Cross verification on high accuracy interpolation filter [K. Kondo, T. Suzuki (Sony)] (missing prior, uploaded by first meeting day)**

This contribution reported cross check results on an enhanced MC filter, called the High Accuracy Interpolation Filter (HAIF), in Tool Experiment3 (TE3) subtest4. In the test, the coding performance and complexity were reportedly measured under common test conditions, which were defined in JCTVC-B300. The proposed tools had been evaluated using the common conditions. Detailed results were summarized in an attached Excel sheet.

The contributor received source code of JCTVC-C078 implementation; and confirmed the results with minor deviations (different platforms).

For low complexity case, HAIF 8 tap reportedly improved BD rate about 4 % in luma. When it is used together with ALF, the gain is increased to 8 %. It was confirmed that HAIF can improve coding efficiency using together with ALF. Therefore there is a reported benefit to use two techniques together.

Encoding time increased about 11 % by HAIF only. Decoding time was increased about 7 %. When HAIF and ALF are used together, encoding time is increased about 15% and decoding time increased about 16 %.

**JCTVC-C164 TE3 subset 4: Results on bi/single filter switching in FIF [K. Kondo, T. Suzuki (Sony)]**

This contribution reported results on enhanced MC filter, Bi/Single filter switching in fixed interpolation filter, in Tool Experiment3 (TE3) subtest4. In the test, the coding performance and complexity were measured under common test conditions, which were defined in JCTVC-B300. Proposed tools had been evaluated on the common conditions. Detailed results were summarized in the attached Excel sheet.

The following observations were reported:

- Decoder run time is reported not to change
- Encoder run time changes to 60% in case of HE
- Encoder runtime reduction – certainly due to single-pass operation.
- For LC, 6-tap filter shown to give approximately 1% BR reduction compared to DCT-IF 6-tap.

Further study was encouraged.

**JCTVC-C247 TE3 subset 4: Cross-verification on bi/single filter switching in FIF [T. Chujoh, K. Kanou, T. Yamakage (Toshiba)] (missing prior, available first day)**

Small differences were reported in cross-checking JCTVC-C164. However, the results werenearlythe same. Different OS platform usage seemed to explain the differences. The contribution did not describe wether the algorithm and software were carefully studied.



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**Conclusion on TE3:**

The following remarks and suggestions were recorded for TE3.

TE 3.1 (warping) – further study (no experiment establishment needed)

TE 3.2 (geometric partitioning) – make a separate experiment (2 methods plus AMP)

TE 3.3 (illumination) – further study.

TE 3.4 (interpolation filters) – an experiment on interpolation filters will be needed anyway

# 6 TE4: Variable length coding

**JCTVC-C261 TE4: Summary of TE4 on variable length coding [X. Wang (Qualcomm)]**

This document summarized the activities in the Tool Experiment TE4 on Variable Length Coding (VLC). A group of five companies and universities had registered for participation in TE4. One TE report, JCTVC-C262, had been submitted on VLC coding for coded block flags.

**JCTVC-C262 TE4: Report on VLC for coded block flag [X. Wang, M. Karczewicz, W.-J. Chien (Qualcomm)]**

Document JCTVC-C262 reported TE results based on a coding scheme presented in a previous proposal JCTVC-B098. In JCTVC-B098, coding schemes for coded block flag both at CU level and at block level were proposed. Due to the fact that the proposed coded block flag coding at CU level is very close to the one introduced in "phase 2" VLC integration, JCTVC-C262 further reported results of coded block flag coding only at block level.

According to the proposal, if a coded block flag for a certain video component at the coding unit level is not zero and the transform block size is smaller than the coding unit size, the coded block flags from the four quarter-sized blocks are grouped and coded together. Due to coded block flag at the coding unit level, the coded block flags for the four quarter-sized blocks cannot all be zero. As a result there are 15 different combinations in total for these flags. A new VLC table was designed and tested. It was reported that on average around 0.2% coding gain can be obtained using the three low complexity coding configurations.

It was noted that the proposal has an interaction with the use of a residual quadtree. The proposal does not apply if residual quadtree encoding with more than two levels is used.

The proposal only applies to the LCEC entropy coding scheme.

The coding gain is rather minor, but the proposal is a small change.

It was suggested that if the proposal is adopted, it should be possible to switch it off in the software, to ease future testing.

Decision: It was agreed to adopt the proposal into the TMuC / TM (provided it does not conflict with other adoptions).

See also the discussion of JCTVC-C277 and JCTVC-C319.

**JCTVC-C288 TE4: Verification results of JCTVC-C262 [T. Yamakage (Toshiba)] (missing prior, available first day)**

This contribution shows verification results of JCTVC-C262 (Report on VLC for coded block flag) for TE4. The contributor started with source code and compiled it themselves to produce executables, but did not study the software algorithmically. Results were reported to be slightly different but not significantly, relative to JCTVC-C262. No mismatch between the encoder and decoder was observed. Encoding and decoding time comparison with the TMuC 0.7.4 anchor (including macro change) showed approximately no impact.



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# 7 TE5: Simplified TMuC intra prediction

**JCTVC-C046 TE5: Summary report on simplification of unified intra prediction [T. K. Tan (NTT DoCoMo), M. Budagavi (TI), J. Lainema (Nokia)]**

This is the summary report for the TE5 on Simplification of Unified Intra Prediction. The description of the experiment can be found in JCTVC-B305r1. This tool experiment was successfully conducted and verified the simplification proposed in JCTVC-B093 and JCTVC-B118 within the context of the unified intra prediction method proposed in JCTVC-B100. Simulation results reportedly show that both methods do not result in a significant loss in coding efficiency compared to the TMuC 0.7.

In the angular intra prediction method, two arrays of reference samples are used, corresponding to a row of samples lying above the current block to be predicted, and a column of samples lying to the left of the same block. Given a dominant prediction direction (horizontal or vertical), one of the reference arrays is defined to be the "main" array and the other array the "side" array. In the prediction process, only samples from the main array are used for prediction when the angle value is positive. When the angle value is negative a per-sample test is performed to determine whether samples from the main or the side array should be used for prediction. Additionally when the side array is used, the index into the array is obtained by a mapping operation that requires either a division operation or a table look-up into a sizable table.

JCTVC-B093 simplifies the prediction process when the angle value is negative. The main array is extended by projecting samples from the side array onto it according to the prediction direction. This projection entails copying a subset of the samples from the side array into the main array. Note that in the copy process, the inverse angle may be replaced with a lookup table. During the prediction process, only the extended main array is used and the same simple linear interpolation formula is used to predict all samples in the block.

JCTVC-B118 replaces divisions in angular intra prediction with a lookup table and additions.

All six coding conditions cases were tested.

Decision: After discussion of the relevant contributions, it was agreed to adopt these two simplifications into the TMuC and TM.

**JCTVC-C042 TE5: Results for simplification of unified intra prediction [T. K. Tan, Frank Bossen (NTT DoCoMo)]**

This contribution reported simulation results for Tool Experiment 5 as described in JCTVC-B305r1. Two tools were compared. The first tool, based on JCTVC-B093, simplifies the angular intra prediction by eliminating the sample-based checking and division steps. The second tool, based on JCTVC-B118, replaces the division in angular intra prediction with a lookup table and additions.

The results reportedly confirmed that both tools do not change the objective performance of the angular prediction process in any significant way. However, the simplified angular prediction (JCTVC-B093) provides the additional advantage of removing bottlenecks in the reference TMuC algorithm to enable a lower-complexity method for intra prediction for which parallel processing can be achieved for all prediction angles on typical SIMD architectures.

**JCTVC-C061 TE5: TI evaluation of unified intra prediction simplifications [M. Budagavi (TI)]**

In HEVC TMuC-0.7 Intra prediction, pixels in current block are predicted from their neighboring left (side reference) and top pixels (main reference) using angular intra prediction. Prediction of pixels from side reference involves division of angle which is computationally complex to implement. Two proposals were made at the last JCT-VC meeting to simplify intra prediction from side reference – JCTVC-B118 and JCTVC-B093. This contribution presents results of evaluation of these two proposals for simplification of intra prediction. The simplifications are achieved using the following two tools: division elimination (JCTVC-B118, JCTVC-B093) and fractional pixel position calculation optimization (JCTVC-



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B093). Based on the results presented in this contribution, the contributor recommended that these two tools be adopted into TMuC and Test Model (TM).

**JCTVC-C100 TE5: Huawei & HiSilicon report on verification test results [L. Liu (HiSilicon), J. Zhou, H. Yu (Huawei)]**

From the results it was confirmed that the proposed methods do not result in any significant difference in coding efficiency compared to the TMuC 0.7.

Both simplified angular prediction (JCTVC-B093) and JCTVC-B118 successfully eliminate the division using a lookup table.

Simplified angular prediction also has the additional benefit of being more suited for typical SIMD architectures due to the single reference array and a single equation for the creation of all predicted samples in the block.

It was recommended that the division elimination and sample creation method of simplified angular prediction be added to the TMuC and Test Model (TM).

**JCTVC-C186 TE5: Results for simplified intra prediction tests by Nokia [J. Lainema, K. Ugur (Nokia)]**

This document reported Nokia results for the TE5 tests and verifies the correctness of the results submitted by other TE participants.

This contribution was based on a separate independent implementation of the proposal.

# 8 TE6: Intra prediction

**JCTVC-C172 TE6: Summary report of intra prediction improvement tool experiments [A. Tabatabai (Sony)]**

This contribution was a summary of Tool Experiment 6, Intra Prediction Improvements. From a total of 6 proposed toolsets, 4 had been evaluated 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-B306_r3.

The tools tested in this tool experiment were as shown in the table below:



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| Tool | Technology | Proponent | Cross-checker(s) |
|---|---|---|---|
| TE6.a.1 | Weighted Bidirectional Prediction (WBP) and Adaptive Sub-block Coding Order (ASCO) | Toshiba<br>JCTVC-B042<br>JCTVC-C079 | Sharp JCTVC-C179<br>Renesas JCTVC-C187 |
| TE6.a.2 | Short distance intra prediction | Huawei & Hisilicon<br>JCTVC-B040<br>JCTVC-C101 | LGE JCTVC-C028<br>DOCOMO JCTVC-C045<br>Ericsson JCTVC-C157<br>Microsoft JCTVC-C271 |
| TE6.a.3 | Overlapped block intra prediction | MediaTek<br>JCTVC-A109<br>JCTVC-C193 | Microsoft JCTVC-C272 |
| TE6.a.4 | Line-based intra prediction | Microsoft<br>JCTVC-A118<br>JCTVC-C270 | Huawei JCTVC-C139<br>DOCOMO JCTVC-C045 |
| TE6.b.1 | Differential coding of intra modes (DCIM) | Sony<br>JCTVC-B109<br>JCTVC-C169 | Sharp JCTVC-C175<br>Panasonic JCTVC-C217 |

## *8.1 TE6.a.1 Weighted Bidirectional Prediction (WBP) and Adaptive Sub-block Coding Order (ASCO)*

**JCTVC-C079 TE6 subset a: Bidirectional intra prediction [T. Shiodera, A. Tanizawa, T. Chujoh, T. Yamakage (Toshiba)]**

This contribution presents the detailed experimental results of Bidirectional Intra Prediction (BIP) for Tool Experiment 6 on intra prediction improvement. BIP was included in the CfP submission of JCTVC-A117 and was proposed in the contribution of JCTVC-B042 at JCT-VC Geneva meeting.

In this document, experimental results using TMuC software under the common test conditions defined by JCTVC-B300 were reported. For the I slice only coding structure, the average BD-rate gain was 2.1% on low complexity conditions and 2.3% on high efficiency conditions without increase of the encoding time and the decoding time.

The reason that the encoding time was not increased was noted to be fast mode decision and turning off some tools that were enabled in the reference configuration – adaptive intra smoothing (AIS) and edge-based prediction. This feature would ordinarily be expected to increase encoding complexity.

It was remarked that JCTVC-C207 encoding optimization improves efficiency by 0.8% with only a fast mode decision technique without adding new tools.

Further study was encouraged.



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**JCTVC-C179 TE6: Cross-check of bi-directional intra-predition results from Toshiba [A. Segall (Sharp)] (missing prior, available first day)**

This contribution cross-checks the bi-directional intra-prediction results provided by Toshiba. This cross-check was performed within the context of TE6 for "Intra high-performance" and "Intra low-complexity" configuration settings. The experimental results reportedly closely matched the rate-distortion results provided by Toshiba. The maximum Y BD Rate differs from the provided results by at most 0.1%.

The Toshiba software source code was used, and the software was reportedly reviewed in detail.

**JCTVC-C187 TE6.a: Cross-check of bidirectional intra prediction (JCTVC-B042) [K. Iwata (Renesas)]**

This document described results of cross-checking the software containing the tool of bidirectional intra prediction (BIP) proposed by Toshiba Corporation. The verification task was reported to have been done successfully and the results matched with proponent's data. The Toshiba software source code was used (without studying the software algorithm).

## *8.2 TE6.a.2 Short distance intra prediction*

**JCTVC-C101 TE6.a: HiSilicon report on short distance intra prediction [C. Lai, Y. Lin (HiSilicon)]**

This document reported the Tool Experiment TE6.a activities related to the evaluation of short distance intra prediction (SDP). Based on the test results achieved so far, line based SDP was reported to provide about 0.9% of bit rate reduction over TMuC anchors for the Intra LC configuration with comparable encoding and decoding time.

The proposed tool includes two kinds of 1x16, 16x1, 2x8, 8x2 and "resample based" prediction.

The "resample based" prediction was not tested, and the HE configuration context was not tested due to software development difficulties.

It was remarked that the LC configuration context may not be the best in which to evaluate such a technique, since it seems to have substantial complexity impact.

Further investigation was encouraged.

**JCTVC-C028 TE6: Verification results of Huawei and Hisilicon proposals (short distance intra prediction using the correlation between lines and pixels) [J. Kim , B. Jeon (LG Electronics)]**

This document reported verification results of JCTVC-C101 on short distance intra prediction. The proponents provided their source coded which was compared under the condition of intra low complexity condition, and the results reportedly matched those of JCTVC-C101.

**JCTVC-C045 TE6.a: Cross verification for line based intra prediction [T. K. Tan, Junya Takiue (NTT DoCoMo)]**

This contribution reported simulation results and cross verification of subset Tool Experiment 6.a as described in JCTVC-B306. This contribution documents the findings based on the study and simulation conducted using the software provided by Huawei and Microsoft.

This contribution was a cross-check verification for both JCTVC-C101 and JCTVC-C270.

Software was received from the proponents, and was somewhat studied to identify the algorithmic differences. In the case of JCTVC-C101 (JCTVC-B040) verification, the software changes were more difficult to identify and study, due to not being controlled by a macro switch.

The results reportedly closely matched those reported for JCTVC-C101 and JCTVC-C270.



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The contributor remarked that deeper analysis of the changes made in these proposals in regard to the prediction process and to the difference coding process was desirable.

The contributor also remarked that it would be beneficial to study harmonization of JCTVC-C101 and JCTVC-C270 as well as refinement of each scheme itself.

**JCTVC-C157 TE6.a: Cross verification of line-based intra prediction [J. Samuelsson, R. Sjöberg, K. Andersson (Ericsson)]**

This contribution contained cross-checking results of Line-based Intra Prediction (LIP) presented by Huawei in JCTVC-B040 and later implemented in TMuC v7.0. Simulations run for the Intra Only Low Delay test case reportedly showed an average BD-rate reduction of 0.9%, matching what was reported in JTCVC-C101.

The software was studied to determine that it matched the described algorithm.

**JCTVC-C271 TE6: Cross-verification of HiSilicon's short distance intra prediction by Microsoft [X. Peng, J. Xu (Microsoft)]**

This document summarized the Tool Experiment TE6 activities related to the cross verification of short distance intra prediction by HiSilicon.

The source code provided by HiSilicon was reported to match with their document description, except that the resample-based intra prediction was disabled. Only intra prediction by exploring the correlations between lines was enabled. In prediction, four modes were allowed on 16x16 and 8x8 blocks, which are 1x16, 16x1, 2x8 and 8x2. Each line had its own prediction mode among nine, which needs to be coded in the bit stream. After prediction, a DCT is applied on the line before it is quantized.

The results reportedly essentially matched those reported in JTCVC-C101.

## *8.3 TE6.a.3 Overlapped block intra prediction*

**JCTVC-C193 Overlapped block intra prediction [K. Zhang, X. Guo, J. An, M. Guo, Y.-W. Huang, S. Lei (MediaTek)]**

This contribution presented the results of overlapped block intra prediction (OBIP) in Tool Experiment TE6.a. In the proposed OBIP method, a position-dependent weighted sum of several possible predictors is treated as the final prediction. The weighting values are obtained by offline training and are fixed during the encoding/decoding procedure. The OBIP method had been implemented into TMuC software. Experimental results reportedly showed that OBIP can attain an average bit-rate reduction of 1% and 1.7% for all-intra high efficiency and low complexity, respectively.

The technique uses a position-dependent weighted combination of three predictors. The weighting combination is selected from one of nine weighting matrices. Only 4x4 and 8x8 blocks use this (as implemented).

Edge-based prediction and planar prediction were turned off (which reportedly has essentially negligible PSNR impact) for reasons of tool incompatibility.

The non-overlapped modes were retained in the scheme as well as the additional OBIP modes.

Further study was proposed, and encouraged.

**JCTVC-C272 TE6: Cross-verification of MediaTek's overlapped block intra prediction by Microsoft [X. Peng, J. Xu (Microsoft)] (missing prior – later provided)**

This contribution reported cross-verification test results for OBIP as proposed in JCTVC-C193. The results reportedly matched those reported in JCTVC-C193.

The software was studied as well as compiled and run.



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## 8.4 TE6.a.4 Line-based intra prediction

**JCTVC-C270 TE6: Report of line-based coding [X. Peng, J. Xu, F. Wu (Microsoft)]**

This document reported experimental results of the line-based coding scheme, which was first presented in JCTVC-A118. The line-based coding takes a line as the reconstruction unit and utilizes content-adaptive prediction filters for accurate predictions. When integrated into the TMuC0.7 software, it reportedly showed 2.1% and 2.4% bit rate saving on average, under all intra high efficiency and low complexity conditions, respectively. Up to 5.1% bit rate saving was reportedly achieved on sequences with rich edges.

Line lengths of 4, 8, and 16 were tested. Syntax is not used to indicate the prediction parameters – rather, they are derived based on the reconstructed area.

The reported encoding and decoding times were approximately doubled or tripled.

It was remarked that the complexity impact of the proposed scheme is substantial.

Further study was encouraged.

Also see remarks above regarding JCTVC-C101.

**JCTVC-C045 TE6.a: Cross verification for line based intra prediction [T. K. Tan, Junya Takiue (NTT DoCoMo)]**

This contribution was also described above. It contained cross verification reporting for both JCTVC-C101 (JCTVC-B040) and JCTVC-C270.

**JCTVC-C139 TE6.a: Huawei & HiSilicon report on cross verification of MSRA's LIC [C. Lai, Y. Lin (HiSilicon), J. Zhou (Huawei)]**

This contribution provided a summary of the cross-checks performed by Huawei Technologies and Hisilicon Technologies on MSRA's LIC (Line Intra Coding) proposal. The simulation results reportedly exactly matched the results in terms of bit rate and PSNR as provided by Microsoft.

## 8.5 TE6.b.1 Differential coding of intra modes (DCIM)

**JCTVC-C169 TE6.b: Experiment results of DCIM [E. Maani, L. Dong, W. Liu (Sony)]**

This document presented experimental results of Differential Coding of Intra Modes (DCIM) under the test conditions defined for Tool Experiment 6.

DCIM uses neighborhood edge estimation to predict Intra prediction direction and differentially encodes the modes with respect to the predicted direction. This enables a higher precision in the Intra prediction directions without substantially increasing the mode signaling overhead. An additional bit is transmitted per block (i.e., PU) to signal to the decoder weather DCIM is used.

MDDT was disabled due to tool implementation compatibility issues, although ROT was used.

Approximately 1.9% overall gain was reported.

For the LC configuration, the work was affected by a bug (bug fix 79) in the underlying TMuC software. The cross verifications with the bug fix had not yet been completed at the time of presentation.

Encoding time is approximately doubled (possibly somewhat slowed by increased use of ROT due to disabling of MDDT); decoding time is reportedly decreased by about 40% (due to disabling of MDDT).

The contributor recommended further study, which was encouraged.



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**JCTVC-C175 TE6.b: Cross verification of differential coding of intra modes (DCIM) [T. Yamamoto, Y. Yasugi (SHARP)] (missing prior, available first day)**

This contribution provided cross-check results of the method called Differential Coding of Intra Modes (DCIM) proposed by Sony in the context of TE6 (TE6.b: Edge based intra prediction). The experiments defined in TE6 were carried out using the software provided by Sony. The experimental results reportedly showed that the proposed method provides 1.9% gain in High Efficiency / Intra Only operation. It was reportedly confirmed that these results matched the results provided by the proponent.

Testing for the LC configuration context had encountered difficulties as described above (bug fix 79).

It was suggested that perhaps, in general, we should not use the "LC" configurations to test techniques that require a substantial complexity increase.

**JCTVC-C217 TE06.b: Cross verification of differential coding of intra modes (DCIM) [V. Drugeon (Panasonic)]**

This contribution was a cross-check for differential coding of intra modes (DCIM). Partial results were provided. The results reportedly closely matched those reported by Sony. The software was studied and determined to match the algorithm description as proposed in July.

**JCTVC-C176 Analysis and improvement of differential coding of intra modes [T. Yamamoto, Y. Yasugi (Sharp)]**

This contribution related to the DCIM technology tested in TE6.

Edge based intra prediction is a method to utilize the gradient of the neighboring samples to decide the direction to predict the target partition. Since one of its variants has been incorporated in the TMuC and the other variant (DCIM: Differential Coding of Intra Modes) was being evaluated in a TE, the Edge based intra prediction was one of the actively researched areas. In this contribution, some analysis of DCIM was presented for providing a better understanding of the technology. Also, some modification and (limited) experimental results were reported – with reported benefits of approximately 0.2% in HE and 0.7% in LC configurations.

It was asked whether the parsing of the bitstream is dependent on the values of the reconstructed samples. The contributor said that it does not.

# 9 TE7: MDDT Simplification

**JCTVC-C027 TE7: Summary report for MDDT Simplification [R. Cohen (Mitsubishi Electric Research Laboratories), C. Yeo (I2R), R. Joshi (Qualcomm)**

The purpose of Tool Experiment 7 (TE7) was to explore the performance and value of simplifying Mode-Dependent Directional Transforms (MDDT) within the HEVC Test Model under Consideration (TMuC). The five proposals submitted for TE7 along with their corresponding cross-verification documents are summarized in the table below.



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| Proponent | Proposal Doc. | TE7 Doc. | Cross-Checks | | | Other related contributions | Remarks if no match |
|---|---|---|---|---|---|---|---|
| I2R | B024 | C037 | C070 (Zhejiang Univ.) | C090 (Peking Univ.) | C158 (Ericsson) | C039 | - |
| Huawei | B039 | C102 | C038 (I2R) | C192 (Yonsei Univ., KGIT) | - | C106 | - |
| Toshiba | B042 | C080 | C035 (MERL) | C103 (Huawei) | - | - | - |
| Beijing Univ. Tech. | B073 | C305 | | | | | Not available prior to meeting, so cross-checkers were reassigned. |
| Peking Univ. | B102 | C089 | C027 (LGE) | C081 (Toshiba) | C190 (ETRI) | - | Some cross-checkers reported crashes, but otherwise results match. |

The proposed schemes generally use a combination of the following techniques to simplify MDDT:

- Exploit symmetry of Intra prediction directions
- Reduce the number of different transforms used
- Use of lower-complexity transform architectures
- Reordering of residuals and reduction of scan orders
- Training of new transforms for use with the above techniques

Abstracts for each of the proposals are as tabulated below:



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| Proponent | Doc. | Tool Abstract |
|---|---|---|
| I2R | JCTVC-B024 | Mode-Dependent Directional Transform (MDDT) was previously introduced to improve transform coding of intra-predicted blocks, and is now a component of the Test Model under Consideration (TMuC). This proposal presents a simplification of the MDDT scheme that requires only two transform matrices: a DCT and a derived KLT. The derived 4x4 KLT also has a structure that can be exploited to reduce the operation count of the transform operation. Derivation of the KLT is based on an assumed image correlation model. Experimental results reportedly show that the proposed technique matches the performance of MDDT even though the approach requires no training, and has significantly lower computation and storage costs. |
| Huawei | JCTVC-B039 | Directional textures exist in the residuals after directional intra predictions. Based on the symmetry of directions, the residual blocks of all directional prediction modes are classified into several groups, with the group number being much less than the number of directional prediction modes. Then, separable KLT is obtained and applied to each group. Simulation results reportedly show that the proposed SMDDT (Simplified MDDT) can use fewer transform matrices to achieve the same or even slightly better coding performance than MDDT in KTA software. |
| Toshiba | JCTVC-B042 | 1 Dimensional Directional Unified Transform (1DDUT) is a spatial transform scheme for intra coding. 1DDUT has additional two 1D directional transform matrices (type A and B) compared with AVC. The transform matrices are pre-determined. Three combinations of these two 1D directional transform matrices are also pre-determined each intra prediction mode. After intra prediction, the residual signal is transformed using pre-determined set of 1D directional transform matrices each prediction mode. And transform coefficients are converted into 1D signals from 2D signals according to the adaptive coding scan, which is a same as the scheme of MDDT. |
| Beijing Univ. Tech. | JCTVC-B073 | Mode Dependent Directional Transform (MDDT) can improve the coding efficiency of AVC but it also brings high computation complexity. In this contribution, a new design for implementing fast MDDT transform through integer lifting steps is presented. First, MDDT is approximated by a proper transform matrix that can be implemented with butterfly-style operation. Then the butterfly-style transform is factored into a series of integer lifting steps to eliminate the need of multiplications. Experimental results reportedly show that the proposed fast MDDT can significantly reduce the computation complexity while introducing negligible loss in the coding efficiency. Due to the merit of integer lifting steps, the proposed fast MDDT is reversible and can reportedly be implemented on hardware easily. |
| Peking Univ. | JCTVC-B102 | To further simplify the mode-dependent directional transform (MDDT), a mode-dependent residual reordering (MDRR) method is proposed. In the proposed MDRR, between the prediction and transform stages, a certain kind of reordering is implemented on the residual samples for each mode in spatial. The reordering is manipulated in a way that the distribution statistics of reordered residual samples present less mode-dependent characteristic. After the reordering, the nine Intra modes in I4MB and I8MB modes will be assigned into three groups, and only one transform matrix is assigned for each group. With the proposed MDRR, the number of transform matrices in MDDT is significantly reduced, while negligible coding performance difference is observed between the MDDT and the proposed scheme. |



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**JCTVC-C310 TE7: Summary report for MDDT Simplification [Robert Cohen, Chuohao Yeo , Rajan Joshi] (late reg.)**

This summary report document provided a brief summary and table of documents related to TE7 on MDDT simplification.

## *9.1 I2R proposed simplification of MDDT*

**JCTVC-C037 TE7: Results for mode-dependent fast separable KLT for block-based intra coding [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 only two transform matrices: a "DCT" and a "derived KLT". The derived 4x4 KLT also reportedly has a structure that can be exploited to reduce the operation count of the transform operation. This contribution provides test results as stipulated in TE7. Experimental results reportedly show that the proposed technique matches the performance of MDDT even though the approach requires no training, and has lower operation count and storage costs.

It was remarked that the "derived KLT" is essentially the same as a form of DST.

The proposal uses two transforms per block size instead of 18. The scheme was applied to two block sizes: 4x4 and 8x8.

A coding loss of 0.1% was reported overall for HE intra-only conditions relative to the anchor (which used MDDT).

It was remarked that an adaptive scan order is part of the scheme.

It was asked how much the coding loss would be if using just one transform. We don't know the answer to that. Roughly 1-2% was suggested as a reasonable guess.

**JCTVC-C070 TE7: Cross-check for I2R proposal on mode-dependent fast separable KLT for block-based intra coding [X. Zhu, L. Yu (Zhejiang Univ.)]**

This contribution presented cross check results of I2R proposal on mode-dependent fast separable KLT for block-based intra coding. Due to lack of time, not all data was checked – only some randomly selected points had been checked. The sequences checked reportedly had the same PSNR and bit rate with the corresponding data given by proponent. The source code was studied and determined to match the proposed algorithm.

**JCTVC-C090 TE7: Cross-verification results of mode-dependent fast separable KLT for block-based intra coding from I2R [X. Zhao, L. Zhang, S. Ma, W. Gao (Peking Univ.)]**

This contribution reported Peking Univ. cross-verification results of the I2R proposal on mode-dependent fast separable KLT for block-based intra coding in response to the Tool Experiment TE7.

Some minor differences were observed between Peking Univ. and I2R results, which could be induced by the different platforms used (Peking Univ.: WindowXP, I2R: Linux). However, the average rate-distortion performance results of I2R and Peking Univ. were reported to be equal.

**JCTVC-C158 TE7: Cross verification of MDDT simplification JCTVC-B024 [K. Andersson (Ericsson)]**

This contribution was a cross-verification of the TE7 MDDT Simplification that was proposed in JCTVC-B024. The PSNRs, bit rates and BD-rate measurements provided by IR2 were matched. The result reportedly shows that the BD bit rate loss is 0.1% and 0.0% for high efficiency configurations all intra and random access respectively compared to the anchor TMuC 0.7 reference configuration. The encoding and decoding time were approximately unaffected.



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**JCTVC-C039 Choice of transforms in MDDT for unified intra prediction [C. Yeo, Y. H. Tan, Z. Li, S. Rahardja (I2R)]**

A simplification of Mode-Dependent Directional Transform (MDDT) was previously proposed in JCTVC-B024 that requires only two transform matrices: a "DCT" and a "derived KLT". However, the choice of transforms in JCTVC-B024 was only specified for the 9 intra prediction modes present in AVC. In this proposal, a choice of transforms is presented for the 34 intra prediction modes possible in the unified intra prediction in TMuC. As in the earlier proposal, only two transform matrices are necessary, and no training is required.

This document provided information on how the proposed scheme was harmonized with Unified Intra Prediction (adding more prediction direction types to the transform selection table) for use in TE7. The testing performed in TE7 used this scheme.

## *9.2 Huawei proposed simplification of MDDT*

**JCTVC-C102 TE7: Symmetry-based simplification of MDDT [H. Yang, J. Zhou, H. Yu (Huawei)]**

In the last meeting, symmetry-based simplification of MDDT (SMDDT) was proposed to reduce the number of transform matrices in the current MDDT implementation. And the SMDDT technique was included in TE 7 for further investigation. According to the TE7 specification, SMDDT has been implemented in the TMuC software and evaluated under the common test conditions since the last meeting. This document reported the performance of the proposed SMDDT technique and discussed the complexity.

Five transforms, with flipping and transposing, were used. Fewer scan orders were used in this proposal than in the I2R proposals. It was claimed that this proposal requires less data storage.

Overall, a 0.1% bit rate increase was reported.

**JCTVC-C038 TE7: Cross-check results of MDDT simplification proposal from Huawei [C. Yeo, Y. H. Tan, Z. Li, S. Rahardja (I2R)]**

This contribution provided a summary of the cross-checks performed by the Institute for Infocomm Research on the Huawei MDDT simplification proposal. The simulation results reportedly closely match the results provided by Huawei. The software source code was studied algorithmically as well as executed.

**JCTVC-C192 TE7: Cross-verification results of Huawei proposal on simplified MDDT for intra prediction residual [Y. Choe, J. Kim (Yonsei Univ.), Y-G. Kim (KGIT)]**

This document reported cross-verification results of simplified MDDT (SMDDT) for intra prediction residual proposed by Huawei, according to the description of TE7. The verification task had been done successfully and the results reportedly match almost exactly those provided by Huawei. The algorithm was studied as well as executing the software.

**JCTVC-C106 Symmetry-based scan order sharing scheme for MDDT [H. Yang, J. Zhou, H. Yu (Huawei)]**

This proposal was used in the TE for the scheme proposed in JCTVC-C102. However, it can reportedly also apply in the context of other schemes and was therefore proposed separately in this contribution.

In this proposal, a symmetry-based scan order (SSO) sharing scheme was proposed to further simplify the mode-dependent directional transform (MDDT). Based on the symmetry among all intra prediction directions, the number of scan maps can reportedly be reduced by the proposed SSO while the coding performance is kept unchanged. The proposal suggested that the proposed SSO scheme be adopted as an improvement of the current MDDT implementation in TMuC.



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When implemented in the current MDDT implementation in TMuC, it was reported that this scan order method results in a memory savings with no performance loss.

Disabling scan order adaptivity reportedly resulted in very little compression performance loss (0.0% to 0.1%). It was remarked that if the gain from scan order adaptivity is that small, perhaps we shouldn't use it (in the HHI coefficient coding scheme as well).

The contributor suggested that a harmonization of simplified MDDT schemes may also be feasible.

Further study was encouraged.

## *9.3 Toshiba proposed simplification of MDDT*

**JCTVC-C080 TE7: One-dimensional directional unified transform [A. Tanizawa, J. Yamaguchi, T. Shiodera, T. Chujoh, T. Yamakage (Toshiba)]**

This contribution presented experimental results of 1 Dimensional Directional Unified Transform (1DDUT) for Tool Experiment 7 (MDDT simplification in HEVC). 1DDUT is a method of reducing the number of transform matrices of MDDT by using a set of pre-defined 1 D transform matrices depending on the intra prediction direction. 1DDUT was included in the CfP submission of JCTVC-A117 and the improved method was proposed in the contribution of JCTVC-B042 at JCT-VC Geneva meeting.

In this document, the experimental results in TMuC software version 0.7.1 on the high efficiency conditions based on the common test conditions for both I slice only coding structure and the random access coding structure defined by TE7 were reported. For I slice only coding structure, the BD-Bit rate gain compared with the anchor (MDDT on) was reported to be 0.1% on average, and for the random access coding structure, the BD-Bit rate gain was reported as 0.0% on average.

**JCTVC-C035 TE7: Cross-verification of the 1D directional unified transform in TMuC [R. Cohen, A. Vetro, H. Sun (Mitsubishi)]**

This document reported the outcome of Mitsubishi Electric Research Laboratory's (MERL) cross-verification of Toshiba's 1D Directional Unified Transform (1DDUT) in TMuC. This activity is part of Tool Experiment 7 on MDDT simplification. A brief analysis of the architecture and software was followed by a summary of experimental results. Differences (negligible, averaging 0.0%) in bit rates and PSNR values can be accounted for by the difference in simulation platforms. The conclusion is that the MERL cross-verification results match those produced by Toshiba.

The software was studied and indicated to be straightforward and to reflect what is described in JCTVC-C080, although a bit different (simpler) than what was proposed in Geneva.

**JCTVC-C103 TE7: Report of cross-checking results for Toshiba proposal [H. Yang, J. Zhou, H. Yu (Huawei)]**

This document reported cross checking results for Toshiba's proposal in TE 7 activities. The decoded sequences matched the reconstructed sequences. The RD data provided by Toshiba were reportedly the same as the results obtained from the crosschecking (with only very minor differences likely due to compiler and platform issues).

## *9.4 Beijing Univ. Tech. proposed simplification of MDDT*

**JCTVC-C305 TE7: Results for Simplification of MDDT Transform [W. Ding, Y. Shi, B. Yin (Beijing Univ. Tech.)] (late)**

MDDT has been implemented as a direct matrix multiplication, which results in higher computation cost than that of an ordinary integer transform. This contribution proposed two symmetric transform matrices to simplify the MDDT matrices. The proposed symmetric transform matrices can be implemented using a



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lifting structure. Experimental results reportedly demonstrate that this proposal reduced the run-time complexity of MDDT with approximately 0.5% coding performance loss.

The operation count was asserted to be lower in this contribution than in the others, by enforcing symmetric transform matrices, which may be why the loss is a bit larger.

The contribution was submitted late, and no cross check was available.

## *9.5 Peking Univ. proposed simplification of MDDT*

**JCTVC-C089 TE7: Results for mode-dependent residual reordering for intra prediction residual [X. Zhao, L. Zhang, S. Ma, W. Gao (Peking Univ.)]**

In this contribution, the Peking Univ. results in response to the Tool Experiment TE7 on MDDT simplification were presented, with the tool description and simulation results. To simplify the mode-dependent directional transform (MDDT), a mode-dependent residual reordering (MDRR) method was proposed. In the proposed MDRR, between the prediction and transform stages, a mode-dependent reordering is implemented on the residual samples for each mode in the spatial domain. After the reordering, a single transform matrix is applied. In all-intra HE configuration, a 0.3% average loss was reported.

**JCTVC-C027 TE7: Verification results of Peking Univ. proposal (mode-dependent residual reordering for intra prediction residual) [J. Kim, B. Jeon (LG Electronics)]**

This document reported verification results of JCTVC-C089 on mode-dependent residual reordering for intra prediction residual, submitted by Peking University. The proponents provide their source code for cross-checking.

For HE intra, the simulation succeeded on all platforms of Window7 32bit and WindowXP 64bit and reportedly produced the same results as what the proponent provided. For HE random access, the simulation succeeded and reportedly produced the same results as what the proponent provided when the same platform was used as what the proponent used.

An accompanying spreadsheet shows different results for V-PSNR for BasketballDrive_1920x1080_QP22 but it was reported to seem to be caused by minor rounding issues. The results of HE random access coding on Windows 7 32bit and on WindowXP 64bit have differences for some sequences such as BQsquare_416x240. An encoder crash occurred for some sequences such as Racehorse_832x480_QP37 on Windows XP 64bit.

The software was not studied – just compiled and run.

**JCTVC-C081 TE7: Cross-verification of mode dependent residual reordering (Peking Univ.) [A. Tanizawa, J. Yamaguchi (Toshiba)]**

This contribution contained cross-checking of software containing the tool "Mode-dependent residual reordering (MDRR)" of JCTVC-B102 proposed by Peking University. The verification task was reported to have been completed successfully and the results reportedly matched those reported in JCTVC-C089. The encoded images matched those of the decoded ones, and the PSNR and bit rate values were reportedly identical to the results provided by Peking University except for one case. In the case of RaceHorses (QP=37), an encoder crash happened. However, the contributor suggested that this might be caused by a bug in the memory access in TMuC version 0.7.

The software was not studied – just compiled and run.

**JCTVC-C190 TE7: Cross-check result of Peking Univ.'s proposal (JCTVC-C089) [J. Kim, S.-C. Lim, H. Y. Kim, H. Lee, J. S. Choi (ETRI)]**

This document presented verification results of JCTVC-C089 proposed by Peking University. Some encoder crashes were experienced. When the encoder did not crash, matching results were obtained.



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The cross-checker verified that no unrelated areas of the software that had been modified, but did not closely study exactly what the proposal part of the software was doing algorithmically.

# 10 TE8: Parallel entropy coding

**JCTVC-C223 TE8 report [G. Martin-Cocher (RIM), M. Budagavi (TI)]**

This contribution was a summary of tool experiment 8, Parallel Entropy Coding. Five proposed tools had been evaluated using the conditions defined in document JCTVC-B308r1. One of the test conditions defined in JVCTV-B308 was an optional hardware test. The hardware cross-verifications had not been performed.

In this TE, five tools had been evaluated according to the conditions defined in JCVTC-B308r1 and their performances had reportedly been verified.

The TE participants, as a group, recommended that the following two tools be adopted into TM and TMuC:

- Coefficient Sign PCP (JCTVC-B088 Section 3.2)
- Coeff Level BinIdx 0 PCP (JCTVC-B088 Section 3.3)

Decision: This was Agreed.

They also recommended that a core/tool experiment be started on the following two tools for improving context processing of significance map, since interaction with HHI_TRANSFORM_CODING needs to be studied more carefully:

- Significance map PCP (JCTVC-B088 Section 3.4)
- Coding order for significance map on bin decoding throughput( JCTVC B036 Section 2)

## *10.1 Coefficient Sign PCP, Coeff Level BinIdx 0 PCP, and significance map PCP*

**JCTVC-C062 TE8: TI parallel context processing (PCP) proposal [M. Budagavi (TI)]**

Context-Adaptive Binary Arithmetic Coding (CABAC) is one of two entropy engines used by the AVC video coding standard. The processing in the CABAC engine is highly serial in nature. Consequently, in order to decode high bit rate video bit-streams in real-time, the CABAC engine needs to be run at extremely high frequencies which consumes a significant amount of power and in the worst case may not be feasible. Techniques to parallelize CABAC can be broadly classified into three categories: bin-level parallelism, syntax element-level parallelism, and slice-level parallelism. Bin-level parallelism techniques such as NBAC/PIPE/V2V parallelize binary arithmetic coder (BAC) of CABAC. However, due to serial bottlenecks in context processing, there is limited overall throughput improvement in the entropy coder. To address this issue, several techniques that parallelize context processing were advocated. The following three techniques for parallelization of context processing (PCP) were presented at the last JCTVC meeting in JCTVC-B088:

- Coefficient Sign PCP (JCTVC-B088 Section 3.2)
- Coeff Level BinIdx 0 PCP (JCTVC-B088 Section 3.3)
- Significance map PCP (JCTVC-B088 Section 3.4)

The first two of these design elements were reported to have no impact on coding efficiency. Further study was suggested for the third topic.



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**JCTVC-C141 TE8: Crosscheck on TI's proposal of parallel context processing by MediaTek [Y.-L. Chang, Y.-W. Huang, S. Lei (MediaTek)]**

This document reported cross-check results for JCTVC-B088 on parallelization of context level processing submitted by Texas Instruments (TI). The first two tools listed above were checked. The software source code for the cross checking was obtained from TI, and was studied and it was concluded that it algorithmically matched the proposed technology design. The verification task was reportedly completed successfully and the results reportedly matched those provided by TI exactly.

**JCTVC-C245 TE8: Cross verification of TI-PCP proposal for significance map [J. Zan, J. Meng, M. T. Islam, D. He (RIM)]**

This contribution reported the results of cross-checking activities performed by RIM on TI parallel context model proposal on significance map (described in JCTVC-B088 Section 3.4). It was reported that the software was studied and determined to match the TI proposal, and the results of the experiments matched those reported by TI.

## *10.2 Coding order for significance map on bin decoding throughput (JCTVC B036 Section 2) and V2V coding tree (JCTVC-B034)*

**JCTVC-C249 TE8: Reports on V2V coding and context modeling by RIM [J. Zan, G. Korodi, J. Meng, M. T. Islam, D. He (RIM)]**

This contribution discussed the coding order for the significance map on bin decoding throughput (JCTVC B036 Section 2) and the V2V coding tree (JCTVC-B034)

This contribution reported experiment results on V2V codes and modified context processing as described in JCTVC-B308 and proposed by the contributor.

According to the plans established in JCTVC-B308, the following tools were tested:

- V2V codes proposed by RIM
- Improved context processing in HEVC

Specifically, the following three tests were run.

- Bernoulli tests of RIM V2V codes against PIPE V2V codes
- Modified context processing in TMuC0.7 against the high efficiency anchors as defined in JCTVC-B300.
- RIM V2V codes in TMuC0.7 against high efficiency anchors as defined in JCTVC-B300.

It was remarked that Huffman coding can be sped up by various techniques – when the VLC table is short, the codewords can be concatenated to create a larger table that requires fewer data fetches to process.

Generally speaking, the RIM proposed code tables are larger than the HHI proposed code tables and they capture more source bits per codeword. It was noted that this causes extra latency/buffering and affects the overhead for flushing out the partially filled codewords when flushing is necessary.

In terms of overall coding efficiency for coding video data, the HHI tables seem very slightly better for predictive coding cases (due to needing fewer bits for flushing at the end of the codestream) and the RIM table seem very slightly better for intra (due to better fitting to entropy due to using larger tables).

Significant overlap with JCTVC-C134 was noted.

In regard to the proposed modified context processing, the motivation is to increase how often the same context is used for the decoding of consecutive bins, so that multiple bins could be processed at once through the finite state machine. For the modified proposal, a 0.0% to 0.1% degradation of coding



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efficiency was reported with a 1.4x to 2.1x effect on the "throughput" for the part of the bitstream that is devoted to these symbols. (See the contribution and JCTVC-C063 for the definition of throughput.)

**JCTVC-C134 Comments on V2V coding for TM/TMuC [D. He, G. Korodi, P. Imthurn, J. Jamias, D. O'Loughlin, G. Martin-Cocher (RIM)]**

This document discussed V2V coding. It was asserted that the design of a V2V tree directly impacts, not only its compression performance, but its throughput, in both software and hardware implementations. The contributor recommended further evaluation of V2V codes by measuring their compression performance, encoding and decoding throughput, sizes, and power consumption in hardware.

The contribution discussed the "Codeset 1" and "Codeset 2" code tables currently in the TMuC.

In Bernoulli tests using the 12 probabilities used in the design of the V2V codes, CABAC and the two codesets were compared. It was remarked that this penalizes CABAC in the comparison, since CABAC was not customized for those specific probabilities.

It was noted that the Bernoulli tests do not include the work needed to select which V2V code to apply in the V2V cases, which is another type of apparent bias against CABAC in the test.

The "codeset 1" tables are generally somewhat smaller, and (perhaps as a result) have slightly less coding efficiency than the "codeset 2" tables (on the specific tested probabilities) – although both have very little excess entropy (0.15% versus 0.12%).

It was remarked that some assumptions may be built into this analysis about how the VLC would be implemented that may not reflect the various ways that optimized encoder and decoders would perform.

It was suggested that some measure such as average bits per look-up operation may be beneficial to collect in experiments.

It was noted that some of the bit rates discussed in the contribution were very high.

It was suggested that some aspects of power consumption may not be captured in the provided power analysis.

It was remarked that area versus power, for example, has a different priority balance in different applications.

The contributor asserted that using a code that has a small number of distinct codeword lengths is desirable.

A participant remarked that the "codeset 2" tables have reduced coding efficiency (approx 0.5%) under some coding conditions in video test classes that result in the use of small slices, due to needing increased overhead bits for flushing the codewords at the end of the slice.

**JCTVC-C063 TE8: Evaluation of RIM parallel context processing (PCP) proposal [V. Sze, M. Budagavi (TI)]**

The coding efficiency loss of RIM PCP was reported to have been evaluated to be between 0.0 to 0.1% using TMuC-0.7 with QC_MDDT disabled. The implemented RIM PCP includes reordering of significant_coeff_flag and last_significant_coeff_flag by context. The update skipping mentioned in the original proposal was not included in the code provided for evaluation; the context updates are still being done serially. The software reports RIM PCP throughput impact to be between 1.4 to 1.9 for significant_coeff_flag amd 1.5 to 2.1 for last_significant_coeff_flag. Test results were reported to have been verified to mostly match with results provided by RIM.

The contributor indicated that using the HHI transform coefficient coding proposal may make it more difficult to take advantage of the throughput increase opportunity.

The contributor indicated that they had studied the software algorithm and that it functioned according to the proposal. It was remarked that some of the computed throughput increase might be difficult to achieve in practice.



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Further study of the context modeling aspect was encouraged.

**JCTVC-C064 TE8: Evaluation of RIM-V2V entropy coding [V. Sze, M. Budagavi (TI)]**

This document reported on the Bernoulli test used to compare the coding efficiency, encoding and decoding throughput of various proposed entropy coding approaches – namely RIM-V2V, HHI-PIPE and BAC. It also provided additional complexity comparison of the RIM-V2V tables versus the HHI-PIPE tables. To measure the coding efficiency, Bernoulli sequences of one billion samples were generated for 12 distinct probabilities. Each of the entropy coding approaches was used to encode the same bin sequence, and the total encoded bits were measured. While the RIM and HHI proposed tables were designed with the specific 12 probabilities in mind, the BAC used existing states, nearest to the 12 probabilities (i.e. BAC was not customized for the probabilities). Furthermore, the tests were not performed in the TMuC context with actual video data. Thus, it was reported to be difficult to draw a conclusion on coding efficiency. The encoding and decoding throughput were estimated based on simulation time. However, since software code for each approach was written in a very different style/structure, it was reported that no conclusion can be drawn on throughput based on the proposed use of simulation time. Further investigation was recommended. Test results given by the Bernoulli test software had been verified to match with results provided by RIM.

The TMuC software has 24 tables from RIM and 12 tables from HHI, and the TMuC document has the 12 tables from HHI, and the 12 tables now proposed by RIM were first documented in a TE plan document.

Similar measurements from the Bernoulli testing were reported in this contribution as what was reported by RIM.

The tested software was reported to have had differences in coding style and degree of optimization. The contributor indicated that it was difficult to determine whether this affected the analysis results.

The contribution indicated that the extra buffering needed by PIPE (relative to CABAC) was an issue.

Area estimates for PIPE were 15x higher than for CABAC.

Further study of the various issues was suggested.

**JCTVC-C280 TE8: Crosscheck result of the transcoder for JCTVC-B034 source selection for V2V entropy coding in HEVC [Y.-L. Chang, Y.-W. Huang, S. Lei (MediaTek)]**

This document reported cross-check activity for the transcoder part of JCTVC-B034 for V2V entropy coding as proposed by Research In Motion (RIM). The verification task was reported to have been done successfully and the results reportedly matched those provided by RIM. There were some small variations (up to -0.12%) reported in random access conditions.

The source code provided by RIM was studied to verify the proposed algorithmic functionality.

**JCTVC-C313 TE8: Crosscheck Result of the Transcoder of JCTVC-B034 for V2V Entropy Coding in HEVC [Y. Zheng , R. Joshi , M. Coban , M. Karczewicz (Qualcomm)] (late reg.)**

The purpose of this late information document was to crosscheck the transcoder implementation of JCTVC-B034 on source selection for V2V entropy coding previoiusly submitted by Research In Motion (RIM). The verification task had reportedly been completed successfully and the results were reported to closely match those provided by RIM.



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# 11 TE9: Large block structures

**JCTVC-C067 TE9: Report on large block structure testing [J. Kim, M. Kim (KAIST), J. Kim, H.-Y. Kim (ETRI), K. Sato (SONY), X. Shen, L. Yu (Zhejiang Univ.), K. Choi, E. S. Jang (Hanyang Univ.), B. Bross (HHI), W.-J. Han (Samsung), J.-K. Jo, S.-N. Park, D. G. Sim, S.-J. Oh (Kwangwoon Univ.)]**

Summary, remarks, and observations:

- Confirms that restrictions CU 64 and TU 32 are reasonable (for current test set)
- Extensive statistic analysis on usage of various block sizes vs. QP/rates

**JCTVC-C140 TE9-2: Report on performance tests for different sets of PU modes by Fraunhofer HHI [B. Bross (Fraunhofer HHI)]**

Summary, remarks, and observations:

- Relates to JCTVC-C200 – TUs spanning PU boundaries has a little advantage
- Using merge syntax for rectangular shapes does not produce loss

**JCTVC-C198 TE9: Simulation results for various max. number of transform quadtree depth [J. Chen, T. Lee, W.-J. Han (Samsung)]**

(The version of JCTVC-C198 prior to Saturday had no results in it.)

Summary, remarks, and observations:

Advantage of RQT in intra comes by allowing more prediction modes

New suggestion is to augment quadtreetulog2maxsize & -minsize by parameter tumaxdepth – none of these parameters is a syntax element to be conveyed to the decoder – would be fixed in the standard (or in a profile)

- Advantage of the new restriction is saving of quadtree signaling bits
- Complexity in intra encoding is decreased to 75% compared to RQT but still increased to approx. 180% compared to the less flexible 2-level method (RQT off in TMuC) vs. BR gain 1.2%
- Decoder complexity is only marginally affected
- Encoders could decide to restrict the number of levels (with penalty on performance) and run faster
- New version of the document that would contain information about using various numbers of levels was not available yet when the document was first discussed
- Reported in revisit:
    - Results relative to RQT on (which is about 1.2% BR decrease and 250% encoder time)
    - Depth 3 HE +0.1% , 75% encoder time; depth 2 +0.3, 60% encoder time
    - Depth 3 LC +0.3%, 82% encoder time, depth 2 0.3, 58% encoder time
- Refer to JCTVC-C311/JCTVC-C312 which implements a fast encoder

**JCTVC-C284 TE9-2.1 Report on forced RQT split according to PUs [A. Segall (Sharp), J. Xu (Microsoft)] (missing prior, provided by third meeting day)**

This contribution confirmed the results of JCTVC-C198 (without an exact match due to different platform usage).



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# 12 TE10: In-loop filtering

**JCTVC-C083 TE10: Summary of TE10 on in-loop filtering [K. Chono, T. Yamakage (TE coordinators)]**

In this tool experiment, in-loop filtering had been tested for the following functionalities:

- Deblocking/debanding filters (four proposals)
- Wiener-based in-loop filters (four proposals)
- Image clipping and offset (two proposals)

As for the details of each proposal, please refer the documents described below.

Seven companies and one university participated as proponents and three companies and one university participated as cross checkers.

Three post filters were investigated. The best of these (in terms of RD perf.) was selected. The difference of the anchor against post filter from JCTVC-C113 was reported as 0.9/0.3 on average.

**JCTVC-C130 TE10 subtest 1: Results of intra deblocking filter testing by SKKU/SKT [J. Yang, K. Won, B. Jeon (SKKU), J. Lim, J. Song (SKT)]**

This document reported TE 10 test results of intra deblocking filter (DF) which was proposed in JCTVC-B075. The proposed method employs exactly the same DF scheme as that in the TMuC, except filter strength control for intra blocks. It is implemented on TMuC 0.7 S/W, and its experimental results under the TE10 subtest 1 procedure reportedly show BDBR gain of 0.6% (intra only), 0.3% (random access), and 0.1% (low delay). Encoding time is reportedly increased less than 1% and decoding time is reportedly the same as the TMuC0.7. The proposed method reportedly provides improved visual quality.

It was remarked that this proposed modification compromises preservation of edges vs. removal of artifacts, and it is difficult to say whether one or the other is better.

**JCTVC-C161 TE10: Cross-verification result of SKKU/SKT deblocking filter [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda (NEC)]**

Summary, remarks, and observations:

- The cross-check found no problem with the software, results were reported to be accurate.
- Visual inspection did not unveil relevant improvements or degradations.
- Method requires to store the directional mode (slight additional complexity).

**JCTVC-C142 TE10 subtest 1: Improved deblocking filter [J. An, K. Zhang, Y. Gao, X. Guo, C.-M. Fu, Y.-W. Huang, S. Lei (MediaTek)]**

This contribution describes MediaTek's proposal of a modified deblocking filter based on the AVC deblocking filter (DF). The modified deblocking was asserted to improve intra block boundaries by using intra mode dependent deblocking filter (MDDF) and modified boundary strength and thresholds (MBST). The modified deblocking filter reportedly outperforms the TMuC0.7 anchor in the objective measure RD sense in all six test configurations. Bit rate reductions were reported as 1.6%, 1.2%, 1.3%, 1.4%, 0.6%, and 0.5% for intra, random access, low delay, intra LC, random access LC, and low delay LC, respectively. Though the visual differences between the IDF and TMuC0.7 anchor are small, some improvements could reportedly be observed, especially in the image areas with obvious texture directions. The encoding time reportedly decreases by 1.8%, and the decoding time increases by 6%, compared to TMuC0.7.



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It was remarked that the report about computation time may not be completely reliable; 3% would mean doubling the complexity of deblocking (according to JCTVC-C147). See also cross-check below.

Further work was encouraged, but it was remarked that complexity should not increase significantly.

**JCTVC-C156 TE10: Cross verification of Mediatek's deblocking filter by Ericsson [A. Norkin, R. Sjöberg, K. Andersson (Ericsson)]**

This contribution reported cross-check activity summarized as follows:

- The PSNR and BD rate match
- The source code does not exactly match the description of JCTVC-B077
- The decoder runtime is approx. 7.5x that of current TMuC deblocking
- Directional filtering seemed to help on the RaceHorses sequence, but it is not as clear whether it is better than the TMuC deblocking on other sequences

**JCTVC-C273 TE10 subset 1: Report of content-adaptive de-blocking [Z. Xiong, X. Sun, J. Xu (Microsoft)]**

This document presented a content-adaptive deblocking scheme to improve the visual quality of block-based compressed video. For large smooth regions with small variation, an extra smoothing deblocking mode was introduced to suppress the blocking artifacts. Experimental results reportedly demonstrate that the proposed method can improve the visual quality while maintaining the objective fidelity of heavily compressed video.

The following discussion remarks were recorded:

- Does not affect complexity compared to current deblocking
- From subjective viewing, flickering was observed (in the all-intra case) which may be caused by the stronger filtering; no significant difference overall.

**JCTVC-C131 TE10 subtest 1: Cross-verification result of Microsoft deblocking filter proposal by SKKU/SKT [J. Yang, K. Won, B. Jeon (SKKU), J. Lim, J. Song (SKT)]**

This contribution confirmed PSNR and bit rate results of JCTVC-C273, reporting essentially the same encoding and decoding time.

**JCTVC-C091 TE10: Conditional joint deblocking-debanding filter [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda (NEC)]**

This contribution presented a performance report on a conditional joint deblocking-debanding filter described in JCTVC-B056. The conditional joint deblocking-debanding filter injects small pseudo noise into images around an intra-block boundary which is supposed to be a part of areas of low detail with subtle changes in pixel intensity. The injected small pseudo noise masks banding noise around intra-block boundaries while keeping the rate-distortion performance with the help of the subsequent Wiener filter. Furthermore, when IBDI is used, it also introduces a random quantization effect on the IBDI output image. The conditional joint deblocking-debanding filter was asserted to significantly improve visual quality of decoded video, especially when IBDI is used. Simulation results reportedly verify that the conditional joint deblocking-debanding filter reduces blocking and banding noise with a negligible impact on the video coding efficiency of the TMuC. It was proposed that the conditional joint deblocking-debanding filter be adopted in the TMuC software and that its performance be further evaluated with toolsets specified in HEVC Test Model.

The following discussion remarks were recorded:

- For low-complexity, no Wiener filter is operated; therefore PSNR decreases, affecting BD rate increase by 1.2% in all-intra (less in inter)



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- Does the deterministic pseudo noise introduce visible temporal artifacts? Could it produce artifacts like e.g. mosquito noise in certain test sequences?
- Is it not possible to do the dithering as postfiltering?
- Should it be better after the Wiener filter?
- Various solutions should be studied.
- This would have quite significant implication on the amount of standard text (e.g. would be necessary to describe tables of pseudo noise, exactly describe the rules of insertion, etc.)

Further experimentation was recommended in particular on a) the best position in the loop b) possible implications on producing artifacts, and c) alternative as post processing.

**JCTVC-C274 TE10 subset 1: Cross- verification of NEC's joint deblocking-debanding filter by Microsoft [X. Xiong, J. Xu (Microsoft)]**

This cross-check report confirmed the RD values of JCTVC-C091, reporting similar encoding/decoding times. No subjective tests were reported in the contribution.

**JCTVC-C143 TE10 subtest 2: Coding unit synchronous picture quadtree-based adaptive loop filter (QALF) [C.-Y. Tsai, C.-M. Fu, C.-Y. Chen, Y.-W. Huang, S. Lei (MediaTek)]**

This contribution described MediaTek's work on adaptive loop filter (ALF), namely coding unit synchronous picture quadtree-based adaptive loop filter (CS-PQALF). The proposed method uses multi-level quadtree partitions to allow local adaptivity for Wiener loop filtering. The partitions boundaries are aligned with the boundaries of the largest coding units (LCUs). Each partition is a basic filter unit (FU) and can be enhanced by different Wiener filters to reduce mean square error between the reconstructed picture and the original picture. In this proposal, the number of encoding passes is reduced from 16, for the ALF in TMuC, to 2, for the CS-PQALF, while reportedly maintaining the good coding efficiency performance of the anchor. Simulation results were compared with the anchor adopted in the subtest 2 of tool experiment 10 (TE 10). The proposed CS-PQALF increases 0.1% and 0.3% BD-rates for high efficiency random access (HE-RA) configuration and high efficiency low delay (HE-LD) configuration, respectively. The encoder execution times are increased by 1% for both HE-RA and HE-LD. The decoder execution times are increased by 3% and 1% for HE-RA and HE-LD, respectively. Note that the software execution time cannot really reflect the reduction of hardware external memory access overhead. Additional experiments on combining four techniques including controlled clipping (JCTVC-C146), improved deblocking filter (JCTVC-C142), quadtree-based adaptive offset (JCTVC-147), and CS-PQALF sreportedly how 2.2% and 2.5% BD-rate reductions for HE-RA and HE-LD, respectively.

The main advantage claimed is reduction of number of coding passes; run time does not really reflect that (encoding/decoding time very slightly increased), memory bandwidth is the more critical issue than computation power.

Adaptive filter sizes include square 3x3 ... 9x9, rhombus 5x5 ... 9x9.

In terms of performance (subjective & objective), a negligible difference was reported compared to TMuC anchors.

Similar reductions appear possible with other methods (see e.g. JCTVC-C082 and JCTVC-C113)

More coefficients must be stored & encoded.

It was asked where would be the best place to encode the filter on/off flag: slice or CU level.

Adaptation of filters was controlled by a quadtree transmitted in slice header (at most 16 partitions per frame), boundary aligned with CU quadtree.



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**JCTVC-C229 TE10 subset 2: Cross check result of MediaTek ALF [I. S. Chong, M. Karczewicz (Qualcomm)]**

This contribution reportedly confirmed the results of JCTVC-C143.

**JCTVC-C173 TE10 subtest 2: Parallel adaptive loop filter [T. Ikai, T. Yamamoto (SHARP)]**

In this contribution, the Parallel adaptive loop filter technique from JCTVC-B064, which was implemented into TMuC0.7, was evaluated according to the TE10 common condition. The proposed technique uses both pre-DF (De-blocking filter) signal and post-DF signal as inputs, where both inputs' weights are optimized with Wiener-filter technique. So the whole system can be seen as one in-loop filter where De-blocking filter and Wiener-based filter are combined. This combination provides coding efficiency improvement as well as the functionality to process the two filters in parallel. The experimental results reportedly showed that the proposed technique provides 0.7% / 0.4% / 0.4% bit rate reduction (IntraOnly / RandamAccess / LowDelay) compared to the anchor, where Sum-modified Laplacian based ALF is used. The complexity of the proposed method was also evaluated and the results reportedly showed that the decoding time is 93% to 96% of the anchor and the encoding time is almost the same as the anchor (100%).

The following remarks and observations were recorded:

- Method: Wiener filter applied to deblock filter input, weighted superposition of de-blocking and loop filter output.
- Filter on/off signaled at CU level, filter parameters (incl. weighting params) signaled at slice header.
- Uses 5x5, 7x7 and 9x9 rhombic filters. Loop filter itself basically identical to TMuC. Also uses 16 passes.
- Slight bit rate decrease compared to anchors.
- Encoding time similar to anchor, decoding time slightly less. Avoids pixel-wise operation.
- Information: It was tried to apply filtering to de-blocking output as well, but that did not result in significant gain.
- Subjectively, there seemed to be a tendency to look sharper, but sometimes this could reproduce more coding artifacts.

**JCTVC-C145 TE10 subtest 2: Crosscheck on SHARP's proposal of adaptive loop filter by MediaTek [C.-Y. Tsai, Y.-W. Huang, S. Lei (MediaTek)]**

This cross-check report confirmed the reported reduction of JCTVC-C173 in BD rates and enc/dec time measurements.

**JCTVC-C082 TE10 subtest 2: Reduction of number of encoding passes for quadtree adaptive loop filter (QALF) [T. Yamakage, T. Chujoh, T. Watanabe (Toshiba)]**

This contribution described an encoding technique to reduce the number of encoder passes for Wiener-based filter design, and detailed experimental results of Quadtree-based Adaptive Loop Filter (QALF) were reported. This is one of the proposals for Subtest 2 (Wiener-based in-loop filters) in Tool Experiment 10 (Loop filtering). The number of additional encoder passes compared to no adaptive loop filter encoding is two by this technique, which is drastically reduced from QC_ALF adopted in TMuC v0.7, while the loss of the coding efficiency from the TMuC 0.7.1 anchor is 0.5%. A supplemental information to show the coding efficiency loss (0.1%) is also provided that compares multi-pass QALF and the proposed 2-pass QALF. Note that the additional passes are not encoding a picture, but filtering a picture that requires less complexity compared to encoding a picture. This technique is also applicable to the methods that adopt block-based filtering control.



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The following remarks and observations were recorded:

- Argument for loop filter vs. post filter: Assurance of the (minimum) quality of the output is desired by industry.
- A slight decrease in decoding time may be caused by the less frequent usage of the loop filter.
- There was discussion about relation between loop filtering and interpolation filtering.
- Obviously the best choice of interpolation filter depends on the loop filter used. However the design of the filter coefficients is not normative.
- The contribution shows that it is possible to reduce the number of encoder passes in ALF coefficient derivation without a large penalty in coding efficiency

**JCTVC-C144 TE10 subtest 2: Crosscheck on TOSHIBA's proposal of adaptive loop filter by MediaTek [C.-M. Fu, Y.-W. Huang, S. Lei (MediaTek)]**

This cross-check report confirmed BD rate values of JCTVC-C082, but encoding/decoding runtime measured may be unreliable.

**JCTVC-C194 TE10 subtest 2: Cross-check results of JCTVC-C082 [Toshiba] Reduction of number of encoding passes for quadtree-based adaptive loop filter (QALF) [P. Wu, S. Paschalakis, N. Sprljan (Mitsubishi Electric)]**

This cross-check report confirmed BD rate values within a small margin (using a different platform), with encoding/decoding runtime slightly different.

**JCTVC-C071 TE10 subset 2: Complexity analysis on Wiener-based in-loop filters [L. Wang, L. Yu (Zhejiang Univ.)]**

In this contribution, the complexity of Wiener-based adaptive in-loop filter (ALF) algorithms (A121, B064, B077, A117) in the subset2 of TE10 was analyzed along with their coding efficiencies. The contribution analyzeed three aspects: i) filter features, ii) encoding time, and iii) decoding time.

The following remarks and observations were recorded:

- Only a few frames of the sequences were used to determine encoding and decoding time, so the numbers may not be reliable. New versions of software which are faster exist in most cases.
- It is not clear which versions of software were used (not distributed by the CE coordinator).

**Conclusions on TE10 subtest 1&2:**

The following overall remarks and observations were recorded:

- Alternative de-blocking proposals do not seem especially interesting at the moment (either no real difference, or too complex)
- Comfort noise insertion for de-banding could be interesting, but needs further study.
- Neither subjective evaluation nor objective measures unveiled substantial differences between the various in-loop filters.
- Reduction of number of passes in optimization in ALF appears possible.
- There is a clear difference between no filtering and filtering (roughly 5% BR gain, with a subjectively noticeable benefit)
- Post filtering suffers from temporal discontinuity.



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- As the loop filter has an influence on other elements of the design, it is important to have one in the TM, but it seems to be less important which one this is. Further experimentation on improvements should go on anyway.
- Regarding the 3-input approach investigated in TE 12 which is another option, subjective viewing was performed. Otherwise, the level of encoder runtime increase of 25% currently seems not to be justified vs. 1% additional BR reduction.
- After some (informal) subjective viewing, a report was given Monday evening: For one case (Park Scene QP37) a majority of test persons indicated that they had observed slight improvement (though there was 2% bit rate reduction by the 3-input method compared to anchor ALF)
- In general, those visual tests may have the problem that they compare sequences encoded at (slightly) different bit rates. This puts a slight disadvantage on methods that have a tendency decrease the bit rate.

**JCTVC-C146 TE10 subtest 3: Controlled clipping [Y.-L. Chang, C.-M. Fu (MediaTek), A. Segall, Y. Su (Sharp), C.-Y. Chen, Y.-W. Huang, S. Lei (MediaTek)]**

This proposal reported MediaTek and Sharp joint work on controlled clipping. Controlled clipping describes a process that clips predicted or reconstructed pixel values to minimum and maximum values that are signaled in the bitstream. The clipping process is applied at four stages, namely post-prediction, post-reconstruction, post-deblocking, and post-adaptive loop filter (post-ALF). Results reportedly show that the proposed controlled clipping achieves average 0.6% and 0.4% BD-rate reductions for high efficiency random access (HE-RA) and high efficiency low delay (HE-LD) configurations, respectively. The encoding time measures were reportedly increased by 2% and 0% for HE-RA and HE-LD, respectively, and the decoder times were reportedly increased by 6% and 2%, respectively.

The following remarks and observations were recorded:

- Clipping parameters are sent in picture level and/or slice level.
- Comparison against post clipping was intended, but no gain was found compared to that. In previous implementation (not joined proposal of two companies), gain was found.
- Would there be a guarantee that clipping at various places in the loop is better than post-clipping? Probably not.
- Further study was encouraged.

**JCTVC-C147 TE10 subtest 3: Quadtree-based adaptive offset [C.-Ming Fu, C.-Y. Chen, Y.-W. Huang, S. Lei (MediaTek)]**

This contribution described a MediaTek proposal of quadtree-based adaptive offset (QAO). QAO consists of two parts, quadtree partitioning and offset compensation. The former splits a picture into multi-level quadtree partitions, and each partition is compensated by one offset compensation method. The latter reduces errors between reconstructed pixels and original samples of a current picture by using four kinds of offset compensation methods, including uniform band offset, non-uniform band offset, cross pattern edge offset, and diagonal cross pattern edge offset. Simulation results reportedly show that in comparison with the TE10 anchor, which enables adaptive loop filter (ALF) and many high efficiency tools of TMuC0.7 as required in JCTVC-B300, this proposal can achieve 1.2% and 2.0% bit rate reductions for high efficiency random access (HE-RA) configurations and high efficiency low delay (HE-LD) configurations, respectively. The encoding time was reportedly increased by 2% and 1% for HE-RA and HE-LD, respectively, and the decoder time was reportedly increased by 9% and 9%, respectively.

The following remarks and observations were recorded:

- Each quadtree partition can switch the mode: Wiener, one of the four offset methods (similar to original Samsung proposal A125)Subjective viewing did not unveil differences



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- Complexity increase would be too high to be justified compared to the small gain
- Further study was encouraged.

**JCTVC-C180 TE10.3: Cross check of MediaTek's proposal on quadtree-based adaptive offset [A. Segall (Sharp)] (missing prior, available first day)**

This contribution reported cross-check activity for the MediaTek proposal on quadtree-based adaptive offset. This cross-check was performed within the context of TE10.

MediaTek sent software, and the experiments were run, and closely matching PSNR results were reported. No visual inspection was done.

# 13 TE11: Motion vector coding

**JCTVC-C293 TE11: Summary report for TE11 on motion vector coding [J. Jung (Orange Labs)]**

This document summarized the activities in Tool Experiment TE11 on motion vector coding. A total of 9 companies or universities had registered to the TE: Sony, Sungkyunkwan University, Samsung, NTT DOCOMO, LGE, HHI, Sharps Labs of America, ETRI / Kyung Hee University and Orange Labs. A few emails were exchanged mainly to coordinate the cross-check activity and exchange the modified versions of the TMuC software. Also it can be noticed that for some topics, either the contribution was cancelled by the proponent (lack of time running the experiment, or insufficient results), or the cross-check was not fully completed (all configurations, or sequences).

Several experiments on motion vector coding had been performed for TE11 with various configurations of the software.

For the Inter mode, it was reported that the MV Competition scheme provides significant gains.

For the Skip, Direct, Merge modes, both Skip + Direct (with MV Competition) and Merge were reported to bring significant gains. The following options were reported to seem possible for the TM:

- Keep Merge only at CU and PU level
- Keep Skip + Direct only at CU level
- Keep Merge at PU level, Skip and Direct at CU level

When MV Competition is concerned (for either Inter, Skip and Direct modes) it was reported that:

- Having a temporal predictor brings gains
- Having the ability to signal the set of predictors (including the ordering of the predictors) brings gains

At this stage, experiments combining IMVP and MV Competition were reported to have failed to achieve noticeable improvements.

**JCTVC-C289 TE11: Report on experiment 3.1.a: Disabling MV competition [J. Jung, G. Clare, S. Pateux (Orange Labs)] (missing IPR statement prior)**

The following remarks and observations were recorded:

- Removing the MV competition on Inter, and Skip/Direct modes reportedly provides an average coding loss of 2.6% to 4.1%. (by tendency higher for RA and LC).
- Decoder runtime reportedly increases by MV competition (not measured on the full set, only QVGA class D) 0.1-2.4%; with the highest increase for the lowest bit rate.

Conclusion: Keep MV competition for inter and skip, considering its compression gain.



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**JCTVC-C132 TE11: Cross-verification result of Orange Labs motion vector competition proposal (3.1a) by SKKU [J. Yang, K. Won, B. Jeon (SKKU)]**

This cross-check report confirmed the results of JCTVC-C289.

**JCTVC-C290 TE11: Report on experiment 3.2.b: MV-Competition on Inter, Skip and Direct modes [J. Jung, G. Clare, S. Pateux (Orange Labs)] (missing IPR statement prior)**

The TMuC reference applies MV-Competition for Inter modes, and Merge. Skip and Direct modes are disabled. This experiment evaluated a configuration with MV-Competition for Inter, Skip and Direct modes, with Merge disabled.

The document reported that the scheme with MV-Competition enabled on Inter, Skip and Direct mode provides on average better results than the current TMuC reference.

Average BR gain was reported as 1.5%, gain on LC was higher – around 2.5-3%.

**JCTVC-C043 TE11: Simulation results of merge/skip (3.2b and 3.2d) [Y. Suzuki, F. Bossen (NTT DoCoMo)]**

The following remarks and observations were recorded:

- Confirmed the results of JCTVC-C290 for the HE case (LC not done).
- Reported increased encoder run time by 10%, with a marginal decoder time impact.
- Experiment 3.2d : Switching off skip, direct, CU merge increases BR by roughly 5%, no impact on encoding/decoding time (only done for HE case).

**JCTVC-C292 TE11: Verification of experiment 3.2.d by NTT DOCOMO [J. Jung, G. Clare, S. Pateux (Orange Labs)] (missing prior, available first day)**

The following remarks and observations were recorded:

- Confirmed the results of JCTVC-C043 3.2d HE cases.
- Additional results on LC were: RA: Skip 8% / Merge 6%, LD: Skip 10% / Merge 6%
- For LC, no results on encoder/decoder run times were provided.

**JCTVC-C199 TE11: Report on experiment 3.2.c: Check skip and merge together [I.-K. Kim , T. Lee , W.-J. Han (Samsung)]**

In this document, the coding efficiency of a block merging process (MRG) and Skip/Direct mode of TMuC software was presented. The bit rate impact of Skip/Direct mode was reported as -0.7% (random access), -2.6% (random access low complexity), 0.1% (low delay) and -2.9% (low delay low complexity) compared to MRG which is turned on by default in the TMuC. This contribution also presented a combination of MRG and Skip/Direct where Skip/Direct was enabled on top of MRG. The reported bit rate impact was -1.2% (random access condition), -2.4% (random access low complexity condition), -0.5% (low delay condition) and -3.3% (low delay low complexity condition).

The following remarks and observations were recorded:

- Compared to configuration skip+direct on CU merge off, 0.5% BR gain on average if both enabled. No significant increase in encoder run time.
- Skip+Direct vs. CU based merging seems not always to be identical in effect (as was assumed before).



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**JCTVC-C191 TE11: Cross-check result of merge/skip (3.2c) S. Jeong, J. Lee, H. Y. Kim, S.-C. Lim (ETRI), K. Kim, H. Lee, G. Park (KHU)**

This cross-check report confirmed the results of JCTVC-C199. The decoder run time was only marginally increased, encoder run time increased around 10+%.

It was remarked that the high gains reported in the LC case may be caused by deficiencies of LCEC vs. PIPE, and some of this may be resolved in "LCEC phase II".

**JCTVC-C166 TE11: Study on motion vector coding (experiment 3.3.a & 3.3.c) [K. Sato (Sony)]**

This contribution reported results of two experiments as follows:

- Experiment -1: Comparison of with & without Temporal Predictor
- Experiment -2: Code Number Swapping of Motion Predictors

The following remarks and observations were recorded:

- Experiments were performed only for 50 frames.
- Average numbers were missing; for experiment 2 the gain seems to be around 0 overall.

**JCTVC-C116 TE11: Cross verification of Sony proposal on motion vector coding [Y.-J. Jeon, B.-M. Jeon (LG Electronics)]**

This cross verification contribution confirmed the results of JCTVC-C166 on experiment 2 (with a reported gain of approximately 0); no cross-check was provided on experiment 1 in the contribution.

**JCTVC-C291 TE11: Report on experiment 3.3.b: "temporally oriented" set of predictors for MV-Competition [J. Jung, G. Clare, S. Pateux (Orange Labs)] (missing IPR statement prior)**

This contribution reported that by changing the order of predictors (temporal first), additional gain is possible – in particular for static background scenes. The contribution included a suggestion to signal the set of predictors in MV competition (potentially different for skip as well) at the slice level. No results on that were available yet.

It was reported that this would come with practically no cost at the decoder, but the encoder would need to do some extra optimization work.

Further work was encouraged

**JCTVC-C308 Cross verification of MV Coding Proposal by JCTVC-C293 [K. Sato (Sony)] (late reg.) (verbally presented in TE11, uploaded after the meeting ended)**

This cross-check contribution was registered very late. When brought up for discussion, it had not yet been uploaded and the contributor verbally reported that the work was not yet complete, but that he results achieved so far had confirmed JCTVC-C291. The contribution was eventually uploaded significantly after the meeting had ended.



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# 14 TE12

## *14.1 TE12: Overall TE12 summary*

**JCTVC-C225 TE12: Summary of evaluation of TMuC tools in TE12 [K. McCann (Samsung/Zetacast)] (missing prior, uploaded first day)**

This contribution was a summary of tool experiment 12 (TE12) on exploring the performance of individual tools in the Test Model under Consideration (TMuC). Detailed results were reported by the TE12 participants in individual input documents.

The work of TE12 was very substantial, and it was a very important effort.

The incremental contribution of each individual tool in the TMuC is highly dependent on the settings of the other tools in use; in effect, it is a multi-dimensional non-linear system. The starting points used in TE12 were the default configurations of the TMuC specified in JCTVC-B300, since these represent the current best estimate of realistic use cases.

Each tool in the TMuC was tested individually as follows.

- Some tools are on/off in nature (e.g. ROT). This type of tool was tested by being turned on (if off in the default configuration) or off (if on in the default configuration) unless it has a direct alternative (see below).
- Some tools have direct alternatives either within the TMuC itself or else added to the software for comparison purposes (e.g. PIPE and the LCEC entropy coding within the TMuC, with CABAC for comparison). This type of tool was tested by being replaced by each direct alternative in turn (e.g. PIPE was tested against both LCEC and CABAC).
- Some tools can have minimum or maximum limits defined (e.g. Large Transform block size). This type of tool was tested by having either the minimum or maximum limit made stricter as appropriate (e.g. maximum transform size being reduced from 64x64 to 32x32).

Tools for which there is no alternative in the TMuC (e.g. inter transforms) were not tested.

In most cases, only one tool at a time was exercised by giving it an alternative setting from that of the default configuration. However, some limited testing of combinations of tools was also performed, in order to improve understanding of the interaction between tools (e.g. between ROT and MDDT).

All of the tools listed in the Tool Experiment 12 test plan were evaluated, with the exception of one encoder-only test on CABAC-based RDO on/off. In most cases the tests used TMuC version 0.7 and subsequent versions of the TMuC released by the Software AHG. However, three of the tests used company-specific branches: PU-Based Merging (tested with TMuC 0.8-hhi-bugfix), Enhanced CIP (tested with 0.7-BBC branch) and ALF default/3-input ALF (tested with 0.7-panasonic branch).

Detailed results were reported by the TE12 participants in individual input documents.

It was anticipated that the results of this work would be used to guide improvements in default operating points. In addition, the TE work provides insight on how the various tools contribute to the overall performance of the TMuC and hence helped inform the process of forming the first Test Model. However, it should be noted that the various tools in TMuC interact in a complex non-linear manner, so that careful interpretation of the results is required.

A total of 70 documents directly relating to TE12 were registered. The categories were as follows:

1. Unit definitions
2. Motion representation
3. Intra-frame prediction
4. Transforms



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5. Filtering
6. Entropy coding
7. Other decoder tools
8. Encoder-only tools

Most subtests used TMuC 0.7, while some used 0.7.x (which would include some bug fixes that do not affect the default configuration). All of the 0.7.x versions should be able to be well compared to the distributed anchors. Some variants are noted below:

- PU merging testing used "0.8 HHI bug fix" software;
- Note that a special patch was used in Enhanced CIP on/off testing as discussed in JCTVC-C213 with cross-check JCTVC-C297, which are not classified here as TE12.
- "0.7 Panasonic branch" was used for 3-input ALF tests (e.g., JCTVC-C214).
- LCEC and PBIC tests used 0.7.4.
- CABAC based RDO on/off encoder-only evaluation was not tested.

**JCTVC-C320 TE12: Summary of results of evaluation of TMuC tools in TE12 [K. McCann (TE coordinator)] (late registration)**

Due to the large effort and large number of contributions involved in TE12, the original summary report for the TE (JCTVC-C225) did not contain a summary of the results. Such a report of results was prepared during the meeting and was reported in this contribution. Although the effort involved in the preparation of this contribution was greatly appreciated, there was insufficient time to properly review the document at the meeting due to the late arrival of the document.

## *14.2 TE12 TMuC coding unit definitions*

**JCTVC-C029 TE12: Report on 64x64 versus 32x32 maximum coding unit size for low complexity configuration [P. Pandit (Harmonic)]**

This contribution presented results for the Max CU size experiment under TE12 for the low complexity configuration. Simulations reportedly showed that when using CU32 size, for Intra only case the average BD-Bit rate gain is about 0.2%, for Random access case the average BD-Bit rate loss is about 7% and for low delay case the average BD-Bit rate loss is about 8.8%. Some comments on the visual quality were also made. Cross verification of the results was reportedly done with Motorola.

- The tested cases included LC configuration for intra, low delay & random access
- Visual comparison was done for QP 37

**JCTVC-C044 TE12: Results for experiments on max CU size, RDOQ and AIS [F. Bossen, T. K. Tan (NTT DoCoMo)]**

Other aspects of this contribution are discussed in another section below.

This contribution reported the simulation results for Tool Experiment 12 as described in JCTVC-B312r5. Three sets of experiments were simulated. The experiments are the comparison of the maximum coding unit (Max CU) size of 32 and 64, the comparison of rate distortion optimized quantization (RDOQ) on and off, and the disabling of the adaptive intra smoothing (AIS) with the default set to always off.

- The tested cases included HE configuration for intra, low-delay & random access
- Decoder run time was 2.5x longer without 64x64 (the reason being related to adaptive scanning in MDDT)



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- With 32x32 and smaller only, there was marginal loss in intra-only, around 3% average for the inter cases
- Most of the gain was in classes B and E (as was the case in JCTVC-C029)

**JCTVC-C259 TE12: Results for experiments on Max CU size [Y. Yu, K. Panusopone, L. Wang, S.-T. Hsiang, F. Ishtiaq (Motorola)]**

Test Experiment 12 was set up at the second JCT-VC meeting. TE12 aimed to explore the performance of individual tools in the Test Model under Consideration (TMuC). As part of TE12, the CU size was tested to decide the best maximum CU size between 32 vs 64. The simulation results were cross checked with NTT Docomo and Harmonic. From the simulation results, it was found that CU size 64 is consistently better than CU size 32. Therefore, the contributor recommended that a maximum CU size 64 should be used in the TMuC.

The results mostly confirmed the findings of JCTVC-C029 and JCTVC-C044 (a different TMuC version was used, with small deviations in PSNR)

It was suggested to possibly restrict the intra case to 32x32 (note: there were currently only 5 prediction directions used in intra 64x64).

## *14.3 TE12 TMuC prediction units*

**JCTVC-C052 TE12.1: Block merging (MRG) test (off vs. on) by Fraunhofer HHI [B. Bross (Fraunhofer HHI)]**

This document reported the results of testing the block merging mode for CUs (MRG) within the scope of tool experiment 12 evaluating TMuC Tools. For the test, MRG was disabled and tested against the MRG-enabled default. In a high efficiency scenario, average bit rate savings up to 0.7% were reported when disabling MRG. In a low complexity scenario, disabling MRG yields average bit rate savings up to 2.9%. MRG disabled encoder runtimes range from 106% to 127% and decoder runtimes from 96% to 116% of the default MRG enabled runtimes have been measured.

Disabling CU based merging (reinvoking skip & direct) gives roughly 1% BR reduction overall.

**JCTVC-C109 TE12.1: Results for PU-based merging by Fraunhofer HHI [B. Bross (Fraunhofer HHI)]**

This document reported the results of testing the block merging mode for PUs (MRG_PU) within the scope of tool experiment 12 evaluating TMuC Tools. For the test, MRG_PU was disabled and tested against the block merging mode for CUs (MRG) default. In a high efficiency scenario, average bit rate savings up to 1.9% were reported when disabling MRG. In a low complexity scenario, disabling MRG yielded average bit rate savings up to 2.4%.

The collection of experiment results was not yet complete. A "Bug fix" done in TMuC 0.8 on the PU based merging that was there before but was switched off by default (wrong RD decision at the encoder – ticket #95 and coding of PU based merging ticket #97 avoiding some unnecessary signaling). The results reportedly showed that PU based merging gives additional gain for the cases tested so far. Implicitly, this replaces CU based merging.

It was commented that proposals with similar goals are in TE11.

**JCTVC-C118 TE12.1 Cross-check report on block merging (MRG) on/off [K. Sugimoto, A. Minezawa, S. Sekiguchi (Mitsubishi Electric)]**

This contribution confirmed the results of JCTVC-C052. Brief checking of parameter settings and software was performed.



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**JCTVC-C231 TE12.1: Results for PU based merging [Y. Suzuki, T.K. Tan, F. Bossen (NTT DoCoMo)] (missing prior, available first day)**

This contribution provided a cross check with more results than JCTVC-C109, with results reported as follows. For HE LD, 1.5% BR gain, 2% for HE RA. Also results were reported on case-by-case basis which show that using only skip/direct (as in JCTVC-C052) BQSquare, BQTerrace and Vidyo3 provide losses.

**JCTVC-C264 TE12: Evaluation of block merging (MRG) [W.-J. Chien, P. Chen, M. Karczewicz (Qualcomm)]**

This contribution confirmed the results of JCTVC-C052. Brief checking of parameter settings and software was done.

It was remark that from the results, CU based merging does not seem to make sense. However, investigation of software related to CU based merging may not have been performed to the detailed extent that could definitely exclude the presence of bugs that would improve the performance if fixed.

## *14.4 TE12 TMuC transform units*

**JCTVC-C056 TE12: Evaluation of transform unit (TU) size [M. Zhou, V. Sze (TI)]**

This document reported the evaluation results of the Transform Unit (TU) size for TE12, and provided a brief complexity analysis of transforms. Experimental results reportedly show that the average coding loss caused by disabling the 64x64 transform is around 0.1% to 0.6%; disabling both 32x32 and 64x64 transforms lead to an average coding loss of 1.1% to 4%. The results also reportedly show that disabling the 4x4 transform leads to huge coding loss. When both the 4x4 and 64x64 transforms are disabled, the average coding loss is increased to 3.9% to 8.3%, and disabling 4x4, 32x32 and 64x64 transforms (i.e. only 8x8 and 16x16 transforms are enabled) can lead to quality degradation of 5.2% to 10.6% on average. Due to the high complexity and limited coding efficiency gain of the 64x64 transform, it was recommended that the 64x64 transform be removed from reference configurations. The contribution also recommended that the quality issues of disabling the 4x4 transform be investigated in the future.

The following remarks and observations were recorded:

- There is relatively small loss when 64x64 transform is disabled (for LD LC case which is worst of all 0.6% on average over all classes, 1.3% average for class E LD LC).
- 32x32 disabling causes larger loss (1 to 3.4% depending on case).
- Disabling 4x4 causes larger loss compared to AVC.
- Almost 4x gate count when 64x64 needs to be implemented compared to 32x32.
- This could be dealt with as a profiling issue; the current test material seems not to benefit too much from using 64x64 (32x32 could be default in the TM, and further study of 64x64 could be performed in the future).

**JCTVC-C105 TE12: Huawei report on max transform unit size evaluation [J. Zhou, D. Wang, H. Yu (Huawei)]**

This document summarized the Tool Experiment TE12 activities related to the evaluation of Max TU Size. This evaluation was performed by Huawei and TI.

- Confirms the results by TI, with a small difference due to the use of Windows vs. Linux.
- The contributor received the parameter files from TI and ran on newly compiled software.



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**JCTVC-C200 TE12.1: Experimental results of transform unit quadtree/2-level test [T. Lee, J. Chen, W.-J. Han (Samsung)]**

This contribution presented the experimental results of TE12 Residual quadtree transform (RQT), which was to explore the performance of RQT in the Test Model under Consideration (TMuC). Experimental results of RQT off compared to TMuC showed 1.2%, 0.5% and 0.2% bit rate savings under intra only, random access and low delay conditions, respectively, in high efficiency settings. It shows 0.6%, -0.2% and 0.8% bit rate savings under the same conditions, respectively, in low complexity settings. This contribution also analyzed the performance and complexity of the current TMuC transform unit design by testing several variants of it: no transform unit across partition boundary and no transform unit splitting inside a partition.

The following remarks and observations were recorded:

- Turning RQT off gives loss in luma PSNR but also has less encoder complexity in the intra case (where the BR increase is 1.2%), in inter cases there is a smaller BR increase but no complexity advantage by turning RQT off.
- Restricting TU to maximum of PU size (disallowing TU across PU partitions gives loss of around 1%.
- Restricting TU not becoming smaller than TU size gives loss as well.
- Conclusion: RQT on would only make sense provided that that the suggestion below would compensate for the complexity.
- Intra prediction mode flag could also be used
- Gain of TU across PU partition boundaries may be due to more efficient CBP
- It could be that gain also comes mainly from asymmetric partitioning
- A new suggestion (related to TE9_C198) was to limit the number of TU quadtree levels by using signaling.
- JCTVC-C276 is also related as well.

These issues are further discussed elsewhere in this report.

**JCTVC-C110 TE12.4: Transform unit quadtree tested against 2-level by Fraunhofer HHI [B. Bross (Fraunhofer HHI)]**

This document reported the results of testing the transform unit quadtree (RQT) against the 2-level representation within the scope of tool experiment 12 evaluating TMuC Tools. The 2-level TU representation was tested against the RQT default. BD-rates from -0.2% up to 0.7% were reported. The encoder runtimes of the 2-level representation vary from 31% of the RQT encoder runtimes for the intra only coding constraint set to 102% of the RQT encoder runtimes for the random access coding constraint sets.

This confirms the results of JCTVC-C200.

## *14.5 TE12 Interpolation filters*

**JCTVC-C050 TE12.2: Interpolation filter SIFO and DIF tested against MOMS by Fraunhofer HHI [B. Bross (Fraunhofer HHI)]**

This document reported the results of testing the 12-tap SIFO and 6-tap DIF interpolation filters against 6-tap MOMS filtering within the scope of tool experiment 12 evaluating TMuC Tools. In a high efficiency configuration scenario, MOMS was tested against the SIFO default. Bit rate savings are highly sequence dependent. Thus, average BD-rates of -4.6% are shown as well as BD-rates of 12% when comparing MOMS to the SIFO reference. The average encoder runtime of MOMS is 62%-68% of the



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SIFO encoder runtime. On the other hand, the average decoder runtime of MOMS is 111% to 122% of the SIFO decoder runtime. In a low complexity scenario, MOMS was tested against the DIF default. MOMS performs better than DIF in terms of coding efficiency with average bit rate savings around 5% while encoder runtimes up to 139% and decoder runtimes up to 133% of the DIF runtimes have been measured.

The following remarks and observations were recorded:

- Results show slight increase of BR (0.3%) for HE case, but reduction of encoding time by roughly 35%, increase of decoding time by roughly 15%
- For LC (6-tap), rougly 6% BR decrease, increase encoding time by roughly 25%, decoding time by >30%
- Note: It is reported that the results may be wrong due to a bug in the fixed-point implementation which is effective in class E (static background)
- Sequence dependent, significant gain comes from BQSquare, BQTerrace, BlowingBubbles, PartyScene
- Uses 12 bit precision in case of IBDI off, 16 bit otherwise.
- Due to usage of IIR filter, also full-pel values are filtered.
- Potentially this implies that 2 buffers are needed (as in the current TMuC implementation). Bringing it to one buffer would certainly affect the performance.

**JCTVC-C087 TE12.2: Experimental results of interpolation filter [T. Chujoh, K. Kanou, T. Yamakage (Toshiba)]**

In this contribution, detailed results of interpolation filters were reported. This is one of reports in Tool Experiment 12: Evaluation of TMuC Tools. The interpolation filter of the high efficiency anchor is SIFO (Switched Interpolation Filter with Offset) and that of the low complexity anchor is DIF (Directional Interpolation Filter). In this experiment, some DCT-IFs (Discrete Cosine Transform – Interpolation Filters) are compared to anchor filters. The experimental results show that the coding gain of DCT-IF 12-tap compared to SIFO in the case of high efficiency anchor is average of 0.1% and the coding gain of DCT-IF 6-tap compared to DIF in the case of low complexity anchor is average of 3.6%. The encoding of DCT-IF 12-tap compared to SIFO in the case of high efficiency anchor is about 2/3 and the decoding time is reportedly decreased by 5%. The encoding and decoding times of DCT-IF 6-tap compared to DIF in the case of low complexity anchor were reportedly stable.

- For HE cases, little gain of DCT-IF 12 (0.1% on average), reduction of encoding time by roughly 30%.
- For LC cases, 1.7% gain on average for DCT-IF 6-tap, no significant increase in encoding time, for 8-tap filter 3.5% gain, increase of encoding time by 10%.
- It was remarked that the performance seems to be highly variable over different sequences, e.g. roughly 14% for BQSquare in LD LC.

**JCTVC-C241 TE12: Crosscheck on interpolation filter: SIFO(DIF)/MOMS [R. Panchal, M. Karczewicz (Qualcomm)]**

The following remarks and observations were recorded for this contribution:

- Confirms results of JCTVC-C050, emphasize different treatment of chroma (higher precision filters) by MOMS (SIFO compared against 0.7)
- Confirm sreport of JCTVC-C087, difference of TMuC 0.7 and 0.8 due to bug fix; 0.8 roughly reduces encoding time by 25%, BR by 0.15% for SIFO



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- Emphasizes that SIFO has additional advantage of illumination comp (not effective in current test set).

**JCTVC-C239 TE12: Report on interpolation filter: SIFO/DIF [R. Panchal, M. Karczewicz (Qualcomm)]**

The following remarks and observations were recorded for this contribution:

- Confirms results of Toshiba (C087)
- Gain of SIFO12 vs. DIF6 in RA/LC 5.5%BR, 200%ET, 115% DT, LD/LC 5.9%, 176%/110%
- Loss of DIF6 vs. SIFO in RA/HE 3.3%BR/59%ET/96%DT, LD/HE 3.9%BR/65%ET/97%DT

**JCTVC-C162 TE12.2: Results on MC interpolation filters [K. Kondo, T. Suzuki (Sony)]**

This document reported the results of MC interpolation filters, especially SIFO/DIF as compared with DCT-IF for interpolation filtering in TE12. In the test, the coding performance and complexity were measured under common test conditions, which were defined in JCTVC-B300. The coding performance and complexity of MOMS were reported in addition to DCT-IF. These results were shown in the second part of the contribution. Detailed results were summarized in an attached Excel sheet.

The contribution confirmed the results of JCTVC-C087, with a slight difference due to different platforms.

Additional results:

- for LC with 6-tap DCT-IF BR reduction 2.8% RA, 0.7% LD, no difference in ET & DT
- for HE with 8-tap DCT-IF RA: BR increase 0.2% / 61% ET, LD: BR 1.1% / 65% ET
- for LC with 4-tap DCT-IF 0.8% BR increase RA, 7.4% BR increase LD still ET roughly 100%

The contribution also confirmed the results of JCTVC-C050, with the following aspects noted:

- Additional results on 4-tap MOMS for LC cases show BR red. 5.4%/6.1% BR red., 7%/6% ET inc. 10%/14% DT inc. for RA/LD cases compared to DIF anchors (note: MOMS with bug)
- Confirms significant gain of MOMS in chroma due to use of longer filter (bilinear in reference cases)
- Analysis of MOMS complexity: Due to usage of an IIR filter, the entire frame needs to be processed first. Memory complexity is significantly increased – higher memory access than conv. 8-tap.

**JCTVC-C197 TE12.2: Results for SIFO-6Tap with DIF tests by Nokia and Qualcomm [K. Ugur, J. Lainema (Nokia), R. Panchal, M. Karczewicz (Qualcomm)]**

This contribution presented the Tool Experiment 12 results on Switched Interpolation Filter with Offset (SIFO) that switches separable and directional interpolation filters with 6 taps.

- BR increase roughly 2% average for HE, BR decrease roughly 3% for LC
- ET roughly 50% increase for LC, 10% decrease for HE
- DT number not known, probably slight decrease in HE, slight increase in LC cases
- Emphasized that switching between directional and 2D filters (at slice level) gives benefit (mostly for LC case)
- Also reports advantage vs. DCT-IF 6-tap, particularly in LD LC gain is achieved over all classes.



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**JCTVC-C201 TE12.2: Experimental results of SIFO (DIF) / DCT-IF [E. Alshina, J. Chen, N. Shlyakhov, A. Alshin, W.-J. Han (Samsung)]**

This document reported the results of the chroma DCT-IF extension within the scope of tool experiment 12 evaluating TMuC Tools. For the test, DCT-IF 6 tap was used to replace the existing default chroma interpolation (bilinear filter for high efficiency and DIF for low complexity). The interpolation filter for luma remained as it was for both high efficiency and low delay configurations, which is SIFO for high efficiency and DIF for low complexity, respectively. Experiments results reportedly showed that, in the high efficiency test configuration, the average BD-rate reduction of Y, Cb, Cr components are 0.2%, 5.5% and 6.6%, respectively, for random access, and 0.5%, 2.5% and 2.9% for low delay. In the low complexity test configuration, the average BD-rate reduction of Y, Cb, Cr components are 0.4, 12.7 and 14.1%, respectively, for random access and 1.4, 12.4 and 15.3% for low delay. Encoding and decoding time was similar to that of anchor software, and deviations exist from measurement inaccuracies.

- Encoding/decoding time increased slightly (2%Enc/7%Dec for LC case) – concern was expressed for this LC case.
- BD BR saving in chroma may not be the best criterion for judgment, as the effect of better chroma interpolation is more about improving the PSNR of the chroma components, and the percentage of total bit rate for chroma is low.
- The current default using bilinear interpolation seems to have a drift or rounding problem in chroma interpolation, and the gains reported may partially relate to the fact that this is resolved by higher-order interpolation.
- The suggestion was made in the contribution to replace the 2-tap filter by DCT-IF 6-tap filter.

**JCTVC-C248 TE12.2: Cross verification on DCT-IF for chroma [T. Chujoh, K. Kanou, T. Yamakage (Toshiba)] (missing prior, available first day)**

This contribution confirmed the results of JCTVC-C201.

**JCTVC-C309 Cross verification of DCT-IF for chroma [T. Suzuki (Sony)] (late reg., uploaded after meeting had ended)**

This late document was reported verbally during the meeting: It referred to JCTVC-C201, and was not finished yet when reviewed. However, the results reportedly confirmed the results appropriately for classes C and D. The actual document contribution was uploaded significantly after the meeting had ended.

**Overall summary of interpolation filter investigations:**

- It would be preferable to have the same chroma filter when doing an experiment where different luma interpolation filters are compared.
- The issue of chroma interpolation should be further investigated and must be better understood.
- MOMS: Good performance, but has open issues. Bug reported, claimed to potentially improve performance for class E. Bidirectional IIR filter requires doubling the memory, and resolving that may reduce the performance.
- SIFO has highest objective gain typically, but higher encoder complexity.
- For DCT-IF, DIF, SIFO in the various configurations (4..12tap) the group decided to provide a table about coding performance and enc./decoder complexity. Kemal Ugur was asked to coordinate a breakout to collect and organized the data to take as a basis for decision.



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## *14.6 TE12 TMuC motion representation*

**JCTVC-C030 TE12: Report on AMP evaluation [E. Francois (Technicolor), L. Guillo (INRIA), A. Ichigaya (NHK), H. Yu (Huawei)] (missing prior, available first day)**

The following remarks and observations were recorded for this contribution:

- Turning AMP off results in 1-2% BR increase for the 4 inter configurations, no large variations over the classes (slightly more gain in class E makes the LD cases a bit better).
- Slight deviations of results were observed on Windows vs. Linux platforms.
- Encoding time was reduced by roughly 33% by turning off AMP.
- The relationship with other methods investigated was in TE3. Block partitioning appears useful, but not necessarily by AMP.

**JCTVC-C104 TE12: Huawei & HiSilicon report on AMP evaluation [X. Zheng (HiSilicon), J. Zhou, H. Yu (Huawei)]**

This report confirmed the results of JCTVC-C030.

**JCTVC-C149 TE12.2: Report on asymmetric motion prediction unit (AMP) on/off [A. Ichigaya, K. Iguchi (NHK)]**

This report confirmed the results of JCTVC-C030.

**JCTVC-C286 TE12.2: Technicolor & INRIA report on AMP evaluation [E. Francois (Technicolor), L. Guillo (INRIA)]**

The report confirmed results of JCTVC-C030.

**JCTVC-C119 TE12.2 report on MV prediction AMVP/IMVP [K. Sugimoto, A. Minezawa, S. Sekiguchi (Mitsubishi Electric)]**

The following remarks and observations were recorded for this contribution:

- Switching IMVP on instead of AMVP produces BR increase (<0.5% on average, 1% for class A), and encoding time also increases slightly.
- IMVP seems not to give value.
- Further investigation of AMVP was performed in TE11.

**JCTVC-C163 TE12.2: Results on MV prediction [K. Sato, T. Suzuki (Sony)]**

This contribution confirmed the results of JCTVC-C119, with identical results at the bitstream level (both run under Linux).

**JCTVC-C265 TE12: Evaluation of adaptive motion vector resolution (AMVRES) [W.-J. Chien, P. Chen, M. Karczewicz (Qualcomm)]**

The following remarks and observations were recorded for this contribution:

- Result were provided only for HE cases
- TE12 result: the BR increase by turning AMVRES off is roughly 0.5%, the effect on encoding time was roughly 10%.
- The new proposal of "unified AMVRES" that adapts to prediction direction results in – 1.4% difference on low delay, 0.6% for RA.



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- Additional results on GPB=1+ AMVRES=0 / GPB=0 + AMVRES=1 shows 4.7% / 3.5% decrease in BR and encoding time increase 215% / 112% compared to LD HE anchor.

**JCTVC-C182 TE12.2: Cross-check of adaptive motion vector resolution (AMVRES) technology in the TMuC software [A. Segall (Sharp)] (missing prior, available first day)**

This contribution confirmed the results of JCTVC-C265.

## *14.7 TE12 TMuC partition-based illumination compensation*

**JCTVC-C041 TE12: Performance of partition based illumination compensation (PBIC) [A. Fujibayashi, S. Kanumuri, F. Bossen, T. K. Tan (NTT DoCoMo)]**

This contribution was a TE12 contribution presenting the performance of Partition Based Illumination Compensation (PBIC) tool integrated into the TMuC software. In addition to the test conditions of TE12, the contribution compared PBIC to two other tools, namely SIFO and GRefMode, present in the TMuC software that can handle illumination changes. This comparison was also done when a linear fade was applied to the test sequences.

The results reportedly showed that PBIC has no impact on coding efficiency for the regular test sequences and a large gain (11-20% depending on the config) for the test sequences with linear fade. PBIC reportedly has a minimal impact (2-5% increase) on encoder/decoder run times. The authors said that this comparison indicated that PBIC is the top performing tool in terms of coding efficiency and has the least increase in encoder run time.

The following remarks and observations were recorded for this contribution:

- For the common conditions test sequences, PBIC gives no gain or even produces a small loss (1%) in low complexity modes (could be due to the entropy coding).
- For the same test sequences (first 2 seconds) with artificial fade (1 s fade out/in each), PBIC was better in terms BR reduction (12% on average) than SIFO (5%, TMuC) and GRefMode (10%, from A124), and less complex.
- For more natural sequences with illumination variations (Nuts, Shuttlestart, Flower), a 2.6% benefit was reported on average.
- It was remarked that cross fades may be more relevant than fade-in/-out

The PBIC proposal seems to be somewhat better than other potential methods of illumination compensation, but shows no gains on the current test set, and it is probably not a high priority to include dedicated tools for illumination variations.

**JCTVC-C232 TE12.7: Verification of JCTVC-C041 (partition based illumination compensation - PBIC) [N. Sprljan, S. Paschalakis, P. Wu (Mitsubishi Electric)]**

This contribution confirmed the results of JCTVC-C041 on the common conditions set, and with some of the artificial fades, although there were some small deviations due to rounding errors. It was reported that the author had investigated the source code.

**JCTVC-C246 TE12.8: Cross-verification of partition-based illumination compensation (PBIC) [P. Onno (Canon)]**

This contribution confirmed the results of JCTVC-C041 on the common conditions set.



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## *14.8 TE12 TMuC filtering*

**JCTVC-C235 TE12: Evaluation of adaptive in-loop filter [I. S. Chong, M. Karczewicz (Qualcomm)]**

The effect of the adaptive in-loop filter on BD measures was reported as follows:

- High complexity
  - Intra : 2.2% (max 4.2% for class A)
  - Random access :3.7% (max 5.8% for class B)
  - Low delay: 5.2% (max 8.5% for class E)
- Low complexity
  - Intra :-2.2%
  - Random access:-4.8%
  - Low delay: -4.3%

Decoding time increased by around 15% (10-20 depending on cases).

The report on encoding time (no significant difference) seems to contradict with the X-check, probably caused the the cluster environment which may not deliver reasonable numbers.

**JCTVC-C129 TE12: Cross verification for adaptive loop filter (ALF) (on vs. off) [Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel)]**

This contribution confirmed the results of JCTVC-C235 in terms of BR and DT; Encoding time seems also not to be consistent (increase by 30% switching ALF off?) due to usage of a computing cluster.

**JCTVC-C153 TE12: Report on deblocking filter [P. Chen, M. Karczewicz (Qualcomm)]**

The following remarks and observations were recorded for this contribution:

- Marginal changes in BD rate were observed.
- The deblocking filter does not have significant impact on PSNR

**JCTVC-C148 TE12: Crosscheck on deblocking filter in TMuC0.7 by MediaTek [Y.-L. Chang, Y.-W. Huang, S. Lei (MediaTek)]**

This contribution confirmed the results of JCTVC-C153 in BD rate.

The encoding/decoding time was roughly 3% lower when deblocking was switched off.

**JCTVC-C214 TE12.5: Results for adaptive loop filter using prediction and residual [M. Narroschke (Panasonic)]**

This contribution was a part of the TE12: It presented the results of the Adaptive loop filter using the prediction and residual as filter inputs. An average Y-BD-rate gain was reported of 1.4% for Intra High Efficiency, 1.3% for Random Access High Efficiency, and 0.8% for Low Delay High Efficiency compared to the anchors. It was proposed to include it in the TM.

The test results were not complete yet due to recent bug fix work (the results were more complete in the cross check).

A gain of roughly 1% average (higher on intra) compared to ALF was reported.

Encoder complexity was roughly 25-30% higher than with ALF.



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Decoder complexity was also increased by roughly 10%.

**JCTVC-C230 TE12: Cross check result of Panasonic's 3-input-ALF [I. S. Chong, M. Karczewicz (Qualcomm)]**

This contribution confirmed the results of JCTVC-C214.

In comparison against ALF, the BD BR improvement was 1.2% for Intra Low Complexity, 1.1% for Random Access Low Complexity, and 0.9% for Low Delay Low Complexity

**JCTVC-C086 Experimental results of ALF on low complexity [T. Chujoh, T. Yamakage (Toshiba)]**

The BR reduction in LC configurations was:

- RA 4.83%/2.77%/7.56% for ALF alone / DCT-IF 6-tap alone / combination
- LD 4.27%/0.67%/7.11% for ALF alone / DCT-IF 6-tap alone / combination

The suggestion of the authors was to adopt ALF in the test model.

It was remarked that the relationship of ALF and interpolation filters still needs to be better understood

**JCTVC-C212 Cross-verification of JCTVC-C086: Experimental results of ALF on low complexity [W.-J. Han (Samsung)]**

This contribution confirmed the BR reduction results reported in other contributions for this feature.

**Overall conclusions on filtering:**

- ALF results were consistent, with average rate gain slightly less than 5%, decoder runtime increased around 15%.
- Encoder runtime reports were not fully consistent due to usage of clusters.
- The relation between interpolation and loop filtering needs to be better understood.
- Comparison against post filter (TE 10) should be considered.

## *14.9 TE12 TMuC intra-frame prediction*

### 14.9.1 Combined intra prediction

**JCTVC-C092 TE12: Report on combined intra prediction evaluation [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda (NEC)]**

This contribution presented a report on Combined Intra Prediction (CIP) evaluation. Simulation results reportedly showed that:

- BD-Rate increases caused by disabling CIP are 0.3%, 0.2%, and 0.1% for the High Coding Efficiency (HCE) All Intra, Random Access, Low Delay coding conditions;
- BD-Rate increases caused by disabling CIP are 0.2%, 0.1%, and 0% for the Low Complexity (LC) All Intra, Random Access, Low Delay coding conditions;
- Encoding time decrease observed by disabling CIP is about 20% for the HCE and LC All-Intra coding conditions; significant encoding time decrease was not observed by disabling CIP in other coding conditions; and
- Significant decoding time decrease was not observed in all coding conditions.



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It was proposed that CIP is not used in default coding configurations in the TMuC software due to its reported small coding gain and that CIP should be re-evaluated on the top of an HEVC test model based coding tool set established as determined by the TE12 results.

It was further noted that when CIP is used, increased encoder complexity (e.g., by 20% for all-intra runtime measure) is needed to determine whether to use CIP or not.

It was suggested that storing some information could be used in the encoder rather than recomputing it, somewhat reducing the encoding runtime increase.

It was remarked that the recursive nature of the processing in the decoder may make it difficult to implement this mode in a highly-optimized fast implementation.

**JCTVC-C174 TE12.3: Report on combined intra prediction [T. Yamamoto, A. Segall (SHARP)] (missing prior, available first day)**

The resultsin this contribution were reported to be consistent with that reported in JCTVC-C092.

**JCTVC-C213 Additional results for combined intra prediction [M. Mrak, T. Davies, D. Flynn, A. Gabriellini (BBC)]**

This document is not actually directly within the planned scope of TE12, but is closely related and is thus discussed in this section.

This document provides further simulation results for the Combined Intra Prediction (CIP) tool. As implemented in TMuC 0.7, the configuration of CIP was reported to be suboptimal. This document proposed improvements to the CIP implementation, and the results reportedly showed that the gain of CIP can be two to three times greater than in the original implementation.

The asserted suboptimality was asserted to be a result of several factors, which include:

- RD search with CIP for one PU splitting type only, as determined by ANG search;
- Suboptimal selection of constants used for CIP prediction and signaling;
- CIP's open-loop component computed without taking into account AIS;
- RD search without CIP when ROT is used.

Some results were shown for a modified CIP, with roughly 0.5% reported improvement beyond that of the prior CIP design proposal on intra conditions. Work on further improvements was reported to be ongoing. It was remarked that some of the new runtime measurement results seem difficult to justify.

After discussion, it was concluded that, for now, CIP should not be in the TM. Further study was encouraged.

**JCTVC-C297 Cross-verification of JCTVC-C213: additional results for combined intra prediction [W.-J. Han (Samsung)] (late registration, missing prior, available first day)**

This contribution was a cross-verification report of JCTVC-C213: additional results for combined intra prediction. Provided source code was investigated. Both encoder and decoder running were done.

TMuC 0.7 software had been used and the provided patch file (several lines of changes) was applied to the software. The provided patch included 1) adjustment of weights between open-loop and close-loop predictors 2) removal of encoder-side penalty due to the fast estimation process of the combined intra prediction. Both changes seem not relevant to the coding tool itself.

All results were reported to be perfectly matched to those of JCTVC-C213.



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## 14.9.2 Adaptive intra smoothing

**JCTVC-C054 TE12.3: Adaptive intra smoothing (AIS) test (off vs. on) by Fraunhofer HHI [B. Bross (Fraunhofer HHI)]**

This document reported results of testing adaptive intra smoothing (AIS) within the scope of tool experiment 12 evaluating TMuC Tools. For the test, "AIS fast" was disabled and tested against the AIS enabled default.

The test was thus testing "adaptive smoothing" versus "always smoothing" which was reported to perform better than using no filter, but the selection of which non-adaptive case works better depends on the configuration of other related coding tools, in particular including UDI.

For an intra coding only constraint set, average bit rate increases between 2.4% and 4% were reported for the fast implementation. Encoder runtimes for this constraint set are 61% of the default AIS enabled implementation.

For the inter-predictive coding constraint sets, the average bit rate increases between 0.4% and 1.5% are smaller. Encoder and decoder runtimes are 92% and 97% of the default AIS enabled runtimes.

It was remarked that the setting of the default operation is part of the proper analysis of the technique. A good analysis should include smoothing always off, smoothing always on, and adaptive smoothing selection.

**JCTVC-C120 TE12.3: Cross-check report on AIS on/off [K. Sugimoto, A. Minezawa, S. Sekiguchi (Mitsubishi Electric)]**

The purpose of this document is to report the result of a cross-check on Adaptive Intra Smoothing ON/OFF conducted by HHI according to the conditions specified in JCTVC-B312. The verification task was reported to have been done successfully and the results reported exactly matched those provided by HHI.

However, some difference in measured encoding time on the same platform was reported for non-AIS operation. The contributor reported that the non-adaptive case was always faster than the adaptive case. This was suggested to be some problem in the random-access case anchor time measures used by the contributor of JCTVC-C054.

The benefit relative to the always off case measured in all intra coding was measured as 0.5-0.6% for intra-only configurations.

**JCTVC-C044 TE12: Results for experiments on max CU size, RDOQ and AIS [F. Bossen, T. K. Tan (NTT DoCoMo)]**

This section discusses the AIS part of this contribution – other parts of the same document were addressed in other categories.

Similar behavior was reported as in the other contributions. Disabling AIS with disabling smoothing always loses about 0.5% relative to using AIS, but makes the encoder run substantially slower (e.g., 40%).

Fast decision encoding reduces the encoding time of AIS, but has an R-D penalty that is actually more severe than just always disabling smoothing.

Decision: As suggested by the contributor, it was agreed to disable AIS and set DEFAULT_IS to 0 in the TM and reference configurations.

This may depend on various factors that could be affected by further study.

This does not affect consideration of proposed modified techniques as suggested in some other related input contributions such as JCTVC-C302, JCTVC-C234 and JCTVC-C269.



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**JCTVC-C053 TE12.3: Adaptive intra smoothing (AIS) test (slow vs. fast) by Fraunhofer HHI [B. Bross (Fraunhofer HHI)]**

This document reported results of testing slow and fast encoder estimations for AIS within the scope of tool experiment 12 evaluating TMuC Tools. For the test, "AIS fast" was enabled and tested against the "AIS slow" default. For an intra coding only constraint set, average bit rate increases between 0.9% and 1.2% were reported for the fast implementation. Encoder runtimes for this constraint set reportedly ranged from 76% to 72% of the default slow implementation. For the inter-predictive coding constraint sets, the average bit rate increases between 0.1% and 0.5% were smaller. Encoder and decoder runtimes are reportedly similar for these cases and deviations cannot be clearly distinguished from measurement inaccuracies.

These results seemed consistent with that reported in JCTVC-C044, specifically consistent with the assertion that "fast AIS" operation performs worse (as tested) than always disabling the smoothing.

**JCTVC-C281 TE12: Evaluation of fast adaptive intra smoothing [M. Coban, Y. Zheng, M. Karczewicz (Qualcomm)]**

This contribution presented test results for the fast adaptive intra smoothing listed in Tool Experiment 12: Evaluation of TMuC Tools.

The related presentation material was requested to be uploaded.

Similar results were reported as described for other contributions on this topic (JCTVC-C044 and JCTVC-C053).

## 14.9.3 Edge-based prediction

**JCTVC-C171 TE12.3: Experimental results of edge based prediction [A. Tabatabai, C. Auyeung (Sony)]**

Contribution JCTVC-C171 presented results of edge based prediction under TE12.3 for the high and the low complexity intra configuration. Simulations reportedly showed that when edge based prediction is disabled, for both high and low complexity intra configuration, the average BD bit rate is reduced by about 0.1%. Cross verification of the results was done with Panasonic. The measured average BD bit rate was the same as measured by Panasonic. However, the results in this contribution have some small differences from the results of Panasonic.

The related presentation material was requested to be uploaded.

The experiments were conducted with TMuC version 0.7.1 with "bug fix 51". Further details regarding macro settings were described in the document.

Visual comparison was not performed.

The minor benefit measured for this coding tool led to the suggestion in the contribution that edge prediction should not be included in the first test model of HEVC. This was agreed.

There are some new related variations discussed in the TE6 context that remained under consideration at the time of discussion of this contribution.

**JCTVC-C216 TE12.3: Results for edge based prediction [V. Drugeon (Panasonic)]**

Similar results were reported as above for JCTVC-C171. The current implementation of edge based prediction in the current TMuC software using the test configuration proposed by TE12 did not show any gain.

Interaction with other coding tools was suggested as the reason that the tested edge-based prediction scheme did not show gain. To test this hypothesis, testing was performed with CIP, ROT, AIS, MDDT, adaptive scan, and unified intra prediction all disabled in the software. In that context the edge-based



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prediction scheme was reported to provide an average gain of 1.8% (with maximum gain of 4.8%) for intra test conditions.

The question was asked how much coding performance was reduced by the disabling of the other intra coding tools – and the contributor indicated that they did not know.

The related presentation material was requested to be uploaded.

A relationship with technology in TE6 was also noted by the contributor.

Further study of similar techniques was suggested by the contributor, toward identifying how such technology may ultimately prove beneficial, depending on the testing context in regard to other coding tools. Such further study was encouraged.

It was agreed that edge based prediction should not be in TM.

### 14.9.4 Planar prediction

**JCTVC-C188 TE12.3: Results for planar prediction tests by Nokia [J. Lainema, K. Ugur, O. Bici (Nokia)]**

This document reported Nokia results for the TE12.3 experiment on disabling planar intra prediction in the TMuC 0.7 environment. Since planar prediction is reported to be a tool to improve subjective quality, rather than objective quality, visual examples demonstrating the claimed benefit of planar prediction were also included.

The contribution also described an asserted inefficiency in indication of the planar intra prediction mode in the low complexity entropy coding configurations, and proposed a fix for that.

In the high efficiency intra coding configuration case, basically no difference in objective performance was measured.

In the low complexity intra coding configuration case, an objective loss of 0.9% in bit rate was reported.

Random access and low delay testing resulted in the expected results – diminished impact in objective terms.

Joint coding of the planar mode flag and the intra split flag was tried for the low complexity configuration case. With this alteration, the objective loss of 0.9% was reduced to a loss of 0.3%.

Artifact examples were shown in the document with QP=32 and 37, showing a substantial decrease in visual artifacts for smooth gradually-changing regions (which are essentially what is modeled by this mode), such as sky areas.

The contributor was asked about the complexity of the technique – who responded that there may actually be a net complexity reduction from the technique, since no residual difference coding is performed when this prediction mode is used (in the way it is currently found in the TMuC).

It was suggested that adapting the quantizer step size in smooth regions may be able to mitigate the illustrated artifacts. The contributor indicated that such techniques may increase encoding complexity and that the handling of block edges in this technique helps avoid blocking artifacts that would be produced in other techniques.

Some interaction with other proposed techniques such as MDDT was also suggested to potentially exist.

The question was asked how often the mode gets selected – this suggested to typically be 10-15% in all intra coding.

A TENTM co-submitter expressed the opinion that the technique substantially helps subjectively.

**JCTVC-C244 TE12.3: Report on planar intra prediction [D. Flynn (BBC)] (missing prior)**

This contribution reviewed before it was available for download, due to network issues.



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This report presented the configuration and results from testing the intra planar prediction mode. When this mode is enabled, there is, for most configurations, no significant change in BD-Rate, with low-complexity configurations, there is a loss of between 0.9% (Intra) and 0.2% (Random Access) BD-Rate. With all configurations, there is a reduction in encoder runtime associated with enabling the intra planar prediction mode.

These results are identical to those produced by Nokia in JCTVC-C188 within tolerance of ±1kbit/sec, ±0.005dB PSNR.

The root cause of the loss in compression performance had not been analyzed. It was reportedly suspected that it is brought about by the combination of the following:

- The planar mode, as implemented, effects an implicit skip=true flag, and it was suspected that the reductions in runtime that the planar mode brings is through the use of the skip flag.
- It was suspected that the error for planar blocks is not distributed uniformly across the block, rather, the error is greatest at the lower and right edges. Such an error can potentially affect subsequent prediction units since no weighting is applied to the distortion calculation.

It was suggested that further study and potential improved harmonization with related coding elements may show some promise for the technique. Further refinement of other elements may also show benefits (e.g., regarding residual skip handling).

Subjectively, the technique was suggested to have a nice matching of adjacent regions that are predicted the same way. But the benefits seem region-dependent (e.g., better for sky than for faces) and dependent on non-normative encoding techniques (e.g., well optimized AVC intra coding looks substantially better than naïve decision encoding).

As currently used, it does actually reduce encoding and decoding runtimes (by roughly 5-8%) – although it was remarked that we should not read too much into small differences in speed in the software at this stage.

A decision on what is to be done in other related areas may affect what we would decide to do with this technology, at least at this stage of study and integration. Somewhat mixed feelings were expressed, but the strength of evidence on this feature at this time did not seem to justify immediate inclusion in the first TM. Further study was encouraged.

## *14.10 TE12 TMuC transforms and coefficient coding*

### 14.10.1 Transform skip flag

#### JCTVC-C047 TE12.4: Transform skip flag test (off vs. on) by Fraunhofer HHI [B. Bross (Fraunhofer HHI)]

This document reported the results of testing the transform skip flag for the transform unit quadtree (RQT_ROOT) within the scope of tool experiment 12 evaluating TMuC Tools. For the test, RQT_ROOT was enabled and tested against the RQT_ROOT disabled default. In a high efficiency scenario, similar performance was reported when enabling RQT_ROOT – with bit rate savings were reported to be around 0.1%. In a low complexity scenario (using LCEC entropy coder), enabling RQT_ROOT reportedly performs better than the default in terms of coding efficiency – with average bit rate savings around 3.6%. Encoder runtimes ranging from 93% to 106% and decoder runtimes from 91% to 103% of the default runtimes had been measured.

It was remarked that this experiment used version 0.7.2, which was modified for "LCEC Phase 2" in 0.7.4. The question was asked about the potential interaction of this proposal with that one.

The transform skip flag handling was asserted to be essentially the same in this proposal as in the Dresden HHI proposal.

The benefit was found primarily when using LCEC entropy coding – will we be keeping that?



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It seemed that if we keep LCEC entropy coding, then we should also use this scheme (pending any conflicting later decisions at the meeting).

**JCTVC-C258 TE12: Evaluation of transform skip flag (RQT_ROOT) [W.-J. Chien, P. Chen, M. Karczewicz (Qualcomm)]**

This contribution was a cross-verification report with similar results as reported in JCTVC-C047.

The algorithm and code was studied in detail – which resulted in a related contribution discussed below.

All test cases were performed.

**JCTVC-C267 Test results of transform skip flag and phase 2 VLC integration [W.-J. Chien, P. Chen, X. Wang, M. Karczewicz (Qualcomm)]**

This contribution was not directly part of the planned TE12, but is sufficiently closely related to merit being considered together with it.

This contribution presented test results for Transform Skip flag (HHI_RQT_ROOT) under "Phase 2 LCEC VLC integration".

According to the simulation results, further investigations and testing should be conducted to indentify the interaction of the transform skip flag and the phase 2 VLC.

If we don't use the residual quadtree scheme, the proposed Phase 2 scheme was reported to provide a similar capability.

If we do use the residual quadtree scheme and the LCEC entropy coding, the proposed skip flag provides a benefit.

And the two schemes have roughly similar actual signaling.

LCEC phase 2 was something planned for integration in Geneva, but was integrated a bit late, and was asserted to have been intended as original Dresden output (based on JCTVC-A119). Similarly, the RQT_ROOT scheme with the skip flag was asserted to have been intended as original Dresden output as well (based on JCTVC-A116).

If we use the residual quadtree approach, it was suggested to use the transform skip flag with the RQT_ROOT scheme. This was agreed.

If we have LCEC entropy coding and don't use the residual quadtree approach, it was suggested to use the "Phase 2" scheme (not yet reviewed). – further discussion of this avenue did not appear necessary.

**JCTVC-C185 Recent improvements of the low complexity entropy coder (LCEC) in TMuC [A. Fuldseth (Cisco), A. Hallapuro, K. Ugur, J. Lainema (Nokia)]**

This contribution was not directly part of the planned TE12, but is sufficiently closely related to merit being considered together with it.

This contribution reports on recent improvements of the low complexity entropy coder (LCEC) in the Test Model under Consideration (TMuC) context.

The low complexity entropy coder (LCEC), based on the JCTVC-A119 HEVC CfP proposal has been adopted into TMuC as described in JCTVC-B205. This has reportedly proved to be a challenging task, especially since the coding structures of the two algorithms are quite different. In particular, the side information parameters of JCTVC-A119 could not be directly mapped to the side information parameters of TMuC and the strategy of JCTVC-A119 had to be modified as appropriate.

LCEC has been integrated into the TMuC software in four phases:

- Phase 0: TMuC v0.1, preliminary version provided by Samsung/BBC.



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- Phase 1: TMuC v0.7, used as anchor in TE12 low complexity configurations, (including the PIPE vs. LCEC experiment).
- Phase 2: TMuC v0.7.4, disabled by default, but evaluated as part of TE12.
- Phase 3: Recent improvements not integrated in the official TMuC software.

In this document, BD-Rate results for LCEC phase 2 and phase 3 relative to phase 1 were provided. Also, results with and without residual quad tree (RQT) and the transform skip flag (HHI_RQT_ROOT) were reported. The reason is that significant side information parameters such as coded block flag (cbf) are treated differently dependent on the values of these RQT parameters. Finally, a comparison between PIPE and LCEC was given.

The Class E sequences reportedly benefit substantially from the proposed scheme.

The gap between LCEC (as proposed) and PIPE was reported to be approximately 10%.

No cross verification of "phase 3" had been done at this point – see TE12 entropy coding testing.

### 14.10.2 MDDT and ROT

**JCTVC-C136 TE12.4: Mode dependent directional transform (MDDT) test (off vs. on) by HKUST [X. Zhang (HKUST)]**

This contribution reported coding performance tests of MDDT according to Tool Experiment 12 JCTVC-B312. Some difficulties were reported in completing the testing process. Incomplete test results were presented for this reason.

0.7.0 software was used.

When MDDT is disabled in the software, ROT is enabled for all block sizes.

When MDDT is enabled in the software, ROT is enabled on some block sizes but not others.

(ROT was integrated first – when MDDT was later integrated, since it applied only to smaller block sizes, the MDDT enabling switch was designed to revert to the prior ROT behavior when MDDT is off.)

The results seem somewhat difficult to interpret because of this behavior. This is not really a simple test of "off" versus "on" for some tool, since the ROT behavior changes when the MDDT behavior changes.

In the HE test cases, "MDDT on with ROT on for large block sizes" versus "MDDT off with ROT on for all block sizes" showed no significant performance difference.

It was remarked that for LC configuration, some bug fix to the entropy coding behavior was made after version 0.7.0 of the software (bug fix 79) – this may call into question the LC results in this contribution.

**JCTVC-C181 TE12.4: Cross-check of rotational transform (ROT) [K. Misra, A. Segall (Sharp)] (missing prior, available first day)**

This contribution cross-checked the performance of the rotational transform in the context of TE12. The experimental results reportedly showed that, with MDDT enabled, using ROT for the large block sizes introduces an average loss (Y BD-rate for each condition) ranging from 0.0% to 0.6%. This closely matched the rate-distortion results provided by Qualcomm.

The software was studied, and was consistent with the description. The 4x4 ROT variant was not tested.

Encoding and decoding time measures were too unstable to provide confident measures.

**JCTVC-C202 TE12.4: Experimental results of MDDT and ROT by Samsung and Qualcomm [E. Alshina, A. Alshin, W.-J. Han (Samsung), R. Joshi, M. Coban (Qualcomm)]**

The presentation for this contribution was requested to be uploaded



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This document described results of three tool evaluation tests on alternative transform field. These experiments were carried out and cross-verified by Samsung and Qualcomm in a framework of TE12 activity.

A modified combination of MDDT and ROT was proposed in the contribution.

The current combination of MDDT and ROT in the TMuC when enabled together, reportedly provides about 2% benefit for HE intra only (and 1% benefit for RA), with about 45% increase in encoding time. The contributor indicated that this degree of coding time increase is not really necessary – and contribution JCTVC-C250 discusses that topic.

The new combination proposed in the contribution reportedly provides about 3% benefit for HE intra only (and 1% benefit for RA).

It was remarked that TE7 also has some other transform modification.

It was noted that there is also a lower-complexity ROT proposal in JCTVC-C096.

A contributor asked if it was possible to estimate the gain from the transform aspects of this and the adaptive scanning that is part of it. There are really two features being tested together here, in terms of scan and transform changes. The opinion was offered that most of the gain is from the scan rather than the transform aspects. Contributions JCTVC-C106, JCTVC-C114, and JCTVC-C263 also discuss adaptive scanning.

Considering the complexity of these features, their inclusion in the TM at this time did not appear justified for the benefit shown.

**JCTVC-C268 TE12: Report on evaluation of MDDT and ROT [R. Joshi, M. Coban, M. Karczewicz (Qualcomm)]**

Roughly consistent results were presented in this contribution as in the others JCTVC-C136, JCTVC-C181, JCTVC-C202.

**JCTVC-C298 TE12.4 Cross-check of unified MDDT/ROT [T. Davies , D. Flynn (BBC)] (late registration, missing prior)**

This contribution document contained cross-check results of JCTVC-C202, specifically on providing a unified framework for MDDT and ROT mode selection. The cross-check had only partially been completed, although the results collected so far matched those proposed in JCTVC-C202.

**JCTVC-C036 Alternative performance measurement of MDDT and ROT in TMuC [R. Cohen, A. Vetro, H. Sun (Mitsubishi)]**

This contribution was not part of the TE, but is included here since it contains closely related information.

This document evaluated the performance of ROT and MDDT both individually and combined in TMuC, using a reference in which both ROT and MDDT were disabled. The results reportedly show that for all-Intra high efficiency conditions in TMuC 0.7, these tools produce average BD-Rate improvements from 1.6% to 2.1%, where ROT slightly outperforms both MDDT and their combination. For random access high efficiency, the gains were reportedly between 0.7% and 0.9%, with a similar relationship among individual and combined tests. Encoder run times approximately doubled for ROT, whereas decoder run times doubled or tripled with MDDT, depending upon the configuration. Possible future improvements were addressed as well.

The need for subjective evaluation was noted.



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### 14.10.3 Transform coefficient coding

**JCTVC-C049 TE12.4: Transform coding HHI tested against Samsung proposal by Fraunhofer HHI [B. Bross (Fraunhofer HHI)]**

This document reported results of testing the transform coefficient coding proposed by Fraunhofer HHI against the transform coefficient coding proposed by Samsung within the scope of tool experiment 12 evaluating TMuC Tools. For the test, the Samsung coding was tested against the HHI coding default. It was reported that the Samsung coding results in 1.3% to 2.0% luma bit rate increase compared the HHI coding. The Samsung coding runtime of the encoder is between 92% and 110% of the HHI coding runtime and the Samsung coding runtime of the decoder is between 98% and 120% of the HHI coding runtime.

The HHI scheme has adaptive scan order, context modeling for the significance map, and context modeling for the absolute coefficient levels.

The Samsung scheme uses fixed scan order and different context modeling.

Contributions JCTVC-C106, JCTVC-C114, and JCTVC-C263 also discussed adaptive scanning.

**JCTVC-C059 TE12: Evaluation of transform coefficient coding (HHI_TRANSFORM_CODING) with tool breakdown [V. Sze, M. Budagavi, M. Zhou (TI)]**

The coding efficiency gain of HHI_TRANSFORM_CODING was evaluated with TMuC-0.7.3 to be between 1.3 to 2.0%. A breakdown of this gain across the three main tools was also studied and reported as follows: adaptive scanning order of significance map (0.2 to 0.4%), proposed context modeling of significance map (0.9 to 1.4%) and a proposed context modeling of coefficient level (0.1 to 0.2%).

The coding efficiency gain of HHI_TRANSFORM_CODING was also evaluated with TMuC-0.7 by the contributor and was reported to have been verified to be a match with results provided by Samsung.

However, the three tools increase the complexity of context modeling – making it more difficult to parallelize for throughput.

Decision: The conclusion was to put the HHI scheme in TM, and further study the complexity issues.

**JCTVC-C203 TE12.4: Experimental results of transform coefficient coding [J. Chen, V. Seregin, W.-J. Han (Samsung)]**

This contribution reported similar results as in JCTVC-C049.

## *14.11 TE12 TMuC entropy coding*

### 14.11.1 PIPE vs. CABAC vs. LCEC

**JCTVC-C048 TE12.6: PIPE and LCEC tested against CABAC by Fraunhofer HHI [B. Bross (Fraunhofer HHI)]**

This document reported results of testing the PIPE and LCEC entropy coders against CABAC within the scope of tool experiment 12 evaluating TMuC Tools. In a high efficiency scenario, CABAC was tested against the PIPE default. Bit rate savings up to 0.3% are shown when using CABAC. In a low complexity scenario, CABAC was tested against the LCEC default. CABAC performed better than LCEC in terms of coding efficiency, with average bit rate savings up to 15.5% while encoder runtimes up to 170% and decoder runtimes up to 113% of the LCEC runtimes had been measured.

- Intra CABAC vs. PIPE 0.2%, PIPE vs. LCEC 12.5%.
- Random access CABAC vs. PIPE 0.3%, PIPE vs. LCEC 15.2%.



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- Low delay CABAC vs. PIPE 0.3%, PIPE vs. LCEC 15.5%.

It was remarked that the RDO encoder decision-making uses CABAC. It seems like this could make a difference.

**JCTVC-C051 TE12.6: PIPE tested against LCEC by Fraunhofer HHI [B. Bross (Fraunhofer HHI)]**

This contribution presented test results that were essentially consistent with those in JCTVC-C048.

**JCTVC-C058 TE12: Evaluation of entropy coders: PIPE tested against CABAC [V. Sze, M. Budagavi (TI)]**

This document reported performance evaluation results of PIPE (Probability Interval Partitioning) in the Test Model under Consideration (TMuC) as part of TE12.

The coding efficiency loss of PIPE over CABAC was reported to be between 0.2 to 0.3% using TMuC-0.7.

These results were reported to have been verified to be a match with results provided by HHI.

Several outstanding issues pertaining to the throughput and complexity regarding the PIPE were discussed in the contribution. The contribution suggested that the difficulty of parallelizing context modeling indicated that more investigation is required to determine how PIPE impacts the overall throughput of the entropy coder. The reported estimated memory size requirement for PIPE is 5x larger than CABAC. The cost of the additional buffers required by PIPE were suggested to also merit additional analysis. More investigation was also requested on how the parallel bitstreams will be handled (i.e. interleaved or separate); if they are interleaved, the complexity and latency implications of the various approaches was requested to be analyzed. The contributor advocated that further study is required on PIPE.

Regarding interleaved versus separate modes of PIPE operation, at the moment the TMuC encoder makes a decision after buffering the bits for the picture, and the decoder follows what the encoder selected.

It was remarked that reduced power requirements may be more important than reduced area requirements.

It was remarked that TE8 studied some related implementation aspects.

**JCTVC-C184 TE12.6: PIPE tested against LCEC by Cisco [A. Fuldseth (Cisco)]**

This document presented TE12 results on PIPE vs. LCEC comparisons. Depending on the configuration (low delay/random access/intra and low complexity/high efficiency), average BD-Rate figures between 12.3% and 18.0% were reported.

It was noted that the quantity of this compression difference may be affected by other proposed modifications.

It was remarked that some degree of encoding optimization (e.g., whether the encoder resets the statistical measures at the beginning of each picture or in some R-D decision-making) may also affect the coding efficiency difference.

### 14.11.2 LCEC "phase 2" testing

**JCTVC-C196 TE12.6: Results for LCEC_PHASE2 tests by Nokia [K. Ugur, A. Hallapuro, J. Lainema (Nokia)]**

This contribution presented Tool Experiment 12 results on LCEC_PHASE2. LCEC_PHASE2 represents the second integration phase of the low complexity entropy coding (LCEC).

A bit rate improvement was reported as follows: Intra 0.3%, random access 0.4%, low delay 1.6%.

The contributor recommended to adopt Phase 2 into the TMuC.



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**JCTVC-C160 TE12: Crosscheck on LCEC phase 2 [P. Chen, M. Karczewicz (Qualcomm)]**

This contribution presents the test results for LCEC tool (phase 2) listed in Tool Experiment 12: Evaluation of TMuC Tools. Similar gains were reported as described in JCTVC-C196.

## *14.12 TE12 TMuC IBDI and transform precision extension*

**JCTVC-C057 TE12: Evaluation of IBDI and TPE (transform precision extension) [M. Zhou (TI)]**

This document reported evaluation results of the IBDI and TPE (Transform Precision Extension) for TE12. Experimental results on TMuC-0.7 reportedly show that the total gain with both the IBDI and TEP turned on is 0.9% to 5.0% on average; the average IBDI gain when TPE is off is 0.8% to 4.7%, and it is reduced to -0.1% to 3.3% when TPE is turned on; the average TPE gain when IBDI is off is 0.8% to 1.4%, but it totally vanishes when IBDI is on; The results also reportedly show that the additional left shift bits in the TPE (1 bit shift in T32x32, 2 bits shift in T16x16, and 3 bits shift in T8x8, respectively) do not provide additional gain compared to the 4 bits left shift across the transforms.

IBDI (Internal Bit-Depth Increase)

- Input data is left shifted by 4 bits before passed to video codec
- Internal data precision of each video coding processing stage increased by 4 bits
- Reference frame has higher precison (8 bits -> 12 bits) which leads to higher memory bandwidth and increased off-chip storage requirements
- IBDI is on in the reference HE configuration, off in LC configurations

TPE (Transform Precision Extension)

- Expands the intermediate data precision after the first-stage of transform.
- The final transform output data precison reamains unchanged.
- Number of TPE extension bits LC configurations (IBDI off): 7 for T8x8, 6 for T16x16, 5 for T32x32 and 4 for T64x46
- Number of TPE extension bits HE configurations (IBDI on): for T8x8, 2 for T16x16, 1 for T32x32 and - for T64x64

It was suggested to study the use of 8 bit reference pictures with 12 bit prediction signals and 12 bit residual signals. It should be easy to modify the software to support it if it is not already configurable in this fashion.

Results are shown in the table below (with rounding control enabled), indicating the range of benefit averaged across all test sequences within a particular configuration, out of 6 configurations total – HE & LC for all-intra, low delay, and random access. The italicized boldface entries are suggested as the particularly important ones:



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| Anchor combination | Combination under Test | Average Gain (BD-rate) |
|---|---|---|
| **IBDI off, TPE off** | **IBDI on, TPE (5,6,7) on** | 0.8% to 5.0% |
| **IBDI off**, TPE off | **IBDI on**, TPE off | ***0.8% to 4.7%*** |
| **IBDI off**, TPE (5,6,7) on | **IBDI on**, TPE (5,6,7) on | -0.1% to 3.3% |
| IBDI off, **TPE off** | IBDI off, **TPE (5,6,7) on** | ***0.8% to 1.4%*** |
| IBDI on**, TPE off** | IBDI on, **TPE (5,6,7) on** | No gain |
| IBDI off**, TPE (4,4,4) on** | IBDI off**, TPE (5,6,7) on** | No gain |

Recommendations from the proponent:

- TPE be turned on in HE and LC configurations by replacing
    - `const int g_iShift8x8    = 7;`
    - `const int g_iShift16x16  = 6;`
    - `const int g_iShift32x32  = 5;`
    - `const int g_iShift64x64  = 4;`
- In TlibCommon\Source\CommonDef.h with
    - `const int g_iShift8x8    = 4;`
    - `const int g_iShift16x16  = 4;`
    - `const int g_iShift32x32  = 4;`
    - `const int g_iShift64x64  = 4;`

In the transform, it was remarked that increased bit depth between the horizontal and vertical transform stages is somewhat burdensome for implementation.

It was also suggested to consider IBDI with 2 bit expansion rather than 4 bit expansion.

The rounding control feature for bidirectional averaging (adopted into TMuC in Geneva) was noted to affect the degree of benefit for these techniques. It was remarked that when the rounding control feature was integrated into the software, an additional encoder distortion measurement improvement for biprediction was also included – which resulted in making the encoder substantially slower while improving its R-D behavior). JCTVC-C253 was suggested to be related to this topic.

It was concluded that the TM should include 12 bit support (i.e., effectively IBDI) and 4-bit TPE. For LC configuration; use TPE, for HE configuration, use IBDI (without additional TPE).

**JCTVC-C088 TE12.7: Experimental results of IBDI [T. Chujoh, T. Yamakage (Toshiba)]**

In this contribution, results of IBDI (Internal Bit-Depth Increase) and TPE (Transform Precision Extension) testing were reported. This is one of reports in Tool Experiment 12: Evaluation of TMuC Tools. The experimental results reportedly show that the coding gain of TPE in the case of intra coding averages about 1% and the coding gain of IBDI in the case of inter is a total of 3% benefit. The encoding and decoding times were reportedly stable.

**JCTVC-C252 TE12: Report on evaluation of internal bit depth increase and transform precision extension [R. Joshi, M. Karczewicz (Qualcomm)]**

Similar results were presented in this contribution as in JCTVC-C057 and JCTVC-C088.



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## *14.13 TE12 TMuC encoder-only aspects*

**JCTVC-C044 TE12: Results for experiments on max CU size, RDOQ and AIS [F. Bossen, T. K. Tan (NTT DoCoMo)]**

This section discusses the RDOQ part of this contribution – other parts of the same document were addressed in other categories.

Rate-distortion optimized quantization (RDOQ) is a well-known technique for improving the rate-distortion performance associated with the encoding of transform coefficients. In the following experiments this optimization is disabled to quantify its contribution to coding efficiency and to encoding time. Only low-complexity configurations were tested. The reduction of encoding time observed when disabling RDOQ ranges from 8 to 17%. While this difference is significant, the drop in BD-rate performance can be signigicant, up to 3.2% on average for the random-access configuration.

It should be noted that the experiments were run on version 0.7 of the software and thus do not include updates to the low-complexity entropy coder (LCEC_PHASE2 macro).

Considering the reported results, the contributor suggested to keep RDOQ enabled by default for future work.

**JCTVC-C238 TE12.8: Results on RDOQ in high efficiency settings [J. Zan, J. Meng, M. T. Islam, D. He (RIM)]**

This contribution reported results of cross-checking activities performed by RIM on RDOQ (described in JCTVC-B312) for all three high-efficiency settings.

Test results had been compared to those generated by Ericsson. For "intra" and "low delay" modes, RIM test results reportedly matched Ericsson's; for the "random access" mode, there is minor (less than 0.1%) differences on four sequences: 1) the PeopleOnStreet sequence on the V component; 2) the Kimono sequence on the U component; 3) the ParkScene sequence on the U and V component; and 4)the RaceHorsesC sequence on the V component. Overall, the difference in results between the RIM and Ericsson tests was reported to be very minor and all the data on the summary tab of the results spreadsheet matched each other.

The test results were reported to have shown that RDOQ is an effective technique to enhance the coding performance (Rate and PSNR) of the video coding algorithm. Specifically, for intra only setting, the gain by using RDOQ on Y-component was reported to be on average 4.7% (in BD-rate); for random access setting, the gain on Y-component was reported to be on average 4.4%; and for low-delay setting, the gain on Y-component was reported to be on average 2.5%. It was observed that RDOQ offers the largest coding performance gain on Class B sequences.

Considering the reported results, the contributor suggested to keep RDOQ enabled by default for future work.

**JCTVC-C159 TE12: Cross verification of RDOQ [K. Andersson (Ericsson)]**

Both low complexity and high efficiency test cases were tested by Ericsson.

Similar results were reported by Ericsson as in the other RDOQ contributions.

Considering the reported results, the contributor suggested to keep RDOQ enabled by default for future work.



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# 15 Project planning and Test Model establishment

## *15.1 Project timeline*

**JCTVC-C022 WG11 USNB contribution: Suggested practices for the HEVC project in the JCT-VC [A. G. Tescher (for USNB to WG11)]**

The USNB to WG11 requested to establish the following practices for the HEVC project in the JCT-VC:

- The group-adopted "Test Model" (which is expected to be produced in version 1 form at the October 2010 meeting) should contain only the minimum set of well-tested tools that together form a coherent design that has been confirmed to show good capability.
- This "minimum set" may include such variations as would be appropriate for forming multiple profiles of the design (but should not otherwise contain significant duplication of functionality).
- In the event that insufficient analysis is available to establish a consensus on the appropriate minimum set of well-tested tools by the October 2010 meeting, it was suggested that obtaining this consensus should be a higher priority than the goal of adopting a version 1 of the Test Model in October 2010.
- An encoder text description, a decoder text specification, and software matching the encoder and decoder algorithms should be provided for the tools in the Test Model within one meeting cycle of the adoption of a tool into the Test Model. (It may be appropriate for the encoder text description to be in a separate document from the decoder specification.)
- Appropriate software coding guidelines should be established and followed to ensure high quality software development of the Test Model.

These aspects were tentatively agreed on Sunday a.m.

**JCTVC-C023 WG11 USNB contribution: HEVC standardization timeline [A. G. Tescher (for USNB to WG11)]**

Considering the timeline plan for the HEVC standardization approval process and the substantial need for maturation of the design and text drafting efforts for this new standard, the USNB to WG11 proposed that the timeline plan should be adjusted to:

- CD ballot to be issued from the April/May 2012 meeting
- DIS (formerly FCD) ballot to be issued from the October 2012 or January 2013 meeting
- FDIS to be issued from the July 2013 meeting.

**JCTVC-C299 UK National Body comments on HEVC Timescales [UKNB to WG11] (late registration, missing prior, available first day)**

The UKNB welcomed the progress that had been made so far in the development of the new High Efficiency Video Coding (HEVC) standard. They said that the creation of the "Test Model under Consideration" has been a useful first step in making the transition from a competitive to a collaborative method of working, and that the momentum that has built up around this approach should be maintained.

They indicated that there is a need to deliver this important new standard to the market in a timely manner, and requested for MPEG to maintain the timescales that were defined in the Call for Proposals, as follows:

- Test model selection by 2010/10
- Final standard approval by 2012/07



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The UKNB further requested MPEG to provide details of the planned intermediate stages of this process, bearing in mind the revised procedural rules to be followed by ISO/IEC JTC 1 and the need to align key steps with the ITU approval process.

Further discussion was then postponed to Wednesday (see below)

**m18579 Comments on HEVC Test Model [CNNB to WG11, late registration, missing prior, available later]**

The Chinese NB to WG11 submitted this late document, which was not registered as a JCT-VC document. Since it was brief, it is quoted below for the record:

> "According to the tentative timeline described in Joint Call for Proposals on Video Compression Technology (W11113), the Test Model of HEVC is expected to be created at the October 2010 meeting.
>
> CNNB believes that a stable version of Test Model with good quality is essential to the further development of the HEVC standard. Each tool in the Test Model shall be well-tested and be confirmed with good performance. The group should give quality and stability as highest priority in the development of the Test Model.
>
> Considering the frequent updates and inadequate testing to the TMuC software during the interim period, CNNB suggests the group adopts only such well-tested tools in the TMuC to create the first version of TM and expects the group could get consensus at this meeting."

These remarks were taken into consideration in the subsequent discussion, which is reported below.

**Schedule plan discussion (held Wednesday)**

The current WG 11 plan / UK suggestion was summarized as follows:

- (WD 11/01) CD July 11 FCD/DIS Jan 12 FDIS July 12.

The WG 11 US NB suggestion was summarized as follows:

- (WD 11/01) CD May 12 FCD/DIS Oct 12 or Jan 13 FDIS July 13.

It was remarked that we could establish a WD now (as the TM is a complete solution), rather than waiting until 2011/01. Later at the meeting, we did agree to issue a WD as an output of this meeting.

Participants remarked that a CD should be

- Stable in text
- Fully verified by software
- Meeting the goals in terms of coding efficiency (roughly)

Opinions expressed were recorded as follows:

- It would take 4-5 meeting cycles to come from current TM to CD.
- H.262 / MPEG-2 took 5 cycles; MPEG-4pt2 took more cycles than that.
- AVC took 16 meeting cycles from initial H.26L reference to final standard (12 to CD).
- "We should keep the meeting schedule to put sufficient pressure on ourselves", vs. "We could release the pressure and always go faster if things come together more quickly than anticipated."
- The market is changing rapidly (and new applications are coming), and the timeline should be kept but could be changed later if necessary.
- Milestones were met so far (CfP/TM), why should we shift the upcoming milestones compared to what was said in the CfP?



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- There is a danger that proprietary codecs may appear and take over if we wait for too long
- Stable software is needed to serve as the basis of the work, and stability of text depends on that (need for verification of the text by the software). And being able to run the software is one thing, having an opportunity to actually understand it and properly specify it is another.
- As code is not well documented yet, and a considerable amount of new tools are still needed to achieve the goal of coding efficiency, it will be difficult to reach adequate maturity in the 3 meeting cycle periods between now and a July 2011 CD milestone.
- Dual track idea – make a low complexity variation first? This might counteract the desire to have most tools in common for LC and HE. We must also make sure that the solution keeps the complexity reasonable – for both HE and LC. Even for an LC variant, there is an HE intent.
- The current specification (as from TMuC) is still far from being mature.
- We still need better understanding about the interaction of the different parts of the TM.
- The compromise then suggested was: CD Jan 12, DIS July 12, FDIS Jan 13.
- The coding efficiency goal is important and should not be missed. The market will take it up when HEVC achieves 50% compared to AVC.
- The compromise suggested would be agreeable if Jan 13 is really staying the end point (i.e. unless a substantial instability or failure of reaching the goals is detected in the standard later).
- This compromise was agreed and recorded in a resolution reported to the WG11 parent body: "The JCT-VC thanks the NBs of UK and US on their valuable comments related to standardization timelines of HEVC. The situation has been considered, particularly including the feasibility of proceeding from the current test model and WD to a mature CD text that fulfils the requirements of the project within the available number of meeting cycles. It is believed that with a timeline of CD 12/02, DIS 12/07 and FDIS 13/01, the probability of producing a high-quality standard would be maximized. With such a timeline being established, only exceptional circumstances should require further delay. Considering comments about the process for test model development that has been followed by the JCT-VC, which were raised by these NB comments and by the NB of China, a document N11642 [a document produced for WG11 corresponding to the content of JCTVC-C401] has been issued which provides an explanation of this process."

## *15.2 Test model design: normative aspects*

**JCTVC-C121 Suggested approach toward HEVC test model creation [S. Sekiguchi, K. Sugimoto (Mitsubishi Electric), more co-authors added later in a revision]**

This joint contribution proposed a suggested approach toward definition of HEVC Test Model, which was suggested to be referred to as the "HM" in the contribution, and addressed some software related issues.

As the result of test model discussion in the last Geneva meeting, the group agreed to define an HEVC Test Model with only the minimum set of well-tested tools that together form a coherent design that is confirmed to show good capability. Given this agreement, this joint contribution proposed a suggested approach toward definition of HM based on contributions available at the Guangzhou meeting. Significant efforts on TE12 have been discussed at the Guangzhou meeting to identify how much coding efficiency and complexity can be seen per each TMuC tool. And the results of other established TEs should have been discussed for evaluation of other tools those are currently not included into the TMuC. However, these tool basis performance reports will be assessments of each individual tool relative to B300 condition, and it is still difficult to identify what is the best minimum combination of available tools. Meanwhile, there are several contributions each of those reports performance evaluation of candidate tool set (JCTVC-C066, JCTVC-C122, JCTVC-C123). It can be found that each tool set evaluated in these separate contributions has some sort of overlap on a common core set of coding tools,



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which means that those core tools have intensively been validated as tool combination via cross-verification by multiple parties.

This joint contribution recommended for the group to review these tool set basis performance evaluations, to identify a base structure of the HM first, and to define the HM by adding other individual tools to the base structure as those would be identified as efficient.

This contribution also addressed some software related issues.

The contribution suggested the following:

- To review all TE reports considering software related issues
- To review all tool set basis performance evaluation reports available at this meeting
- To define a base structure of HM first that follows "one tool per one functionality"
- To define the HM by adding only the currently available tools, which will be evaluated by TEs and provides sufficient coding gain at agreeable complexity, to the base structure of HM

**JCTVC-C122 A suggested starting point for HEVC test model [K. Sugimoto, S. Sekiguchi (Mitsubishi Electric), more co-authors added later in a revision]**

This contribution proposed a set of TMuC coding tools for both high-efficiency and low-complexity conditions, as a starting point of HEVC Test Model (HM) with experimental data jointly verified by multiple companies. The proposed toolset reportedly followed a "one tool per one functionality" principle and was asserted to achieve reasonable coding efficiency relative to the TMuC anchor used for TE12 assessment, while reducing encoding and decoding time significantly. The contributors recommended to construct a base structure of the HM based on the suggested toolset and consider further additions of other tools via careful assessment of all TE results for creation of HM.

It was noted that the anchor used in this contribution had LCEC phase 2 enabled, but was otherwise encoded according to JCTVC-B300 with TMuC 0.7.4.

The HE variation proposed in the contribution is shown as follows, with topics identified as open during the discussion being shown in italic font:

| **Tool name** | **TMuC default setting (JCTVC-B300)** | **Proposed setting** | **Parameters for proposed setting** |
|---|---|---|---|
| **Coding unit** | Min size: 8x8<br>Max size: 64x64 | Same as B300 | Same as B300 |
| **Transform unit** | *Quadtree* | *Samsung based* | *QuadTreeTUFlag : 0* |
| **Large transform** | Max size: 64 | Max size: 32 | QuadTreeTULog2MaxSize : 5<br>MaxTrSize : 32 |
| **Angular Intra Prediction** | I64: 5 modes<br>*I32: 34 modes*<br>*I16: 34 modes*<br>*I8: 34 modes*<br>I4: 17 modes<br>I2: 3 modes<br>*(non-norm?)* | I64: 5 modes<br>*I32: 17 modes*<br>*I16: 17 modes*<br>*I8: 17 modes*<br>I4: 17 modes<br>I2: 3 modes<br>*(non-norm?)* | #if UNIFIED_DIRECTIONAL_INTRA<br>const UChar<br>g_aucIntraModeNumAng[7] =<br>{3, // 2x2<br>17, // 4x4<br>17, // 8x8<br>17, // 16x16<br>17, // 32x32<br>5, // 64x64<br>5 // 128x128}; |



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| | | | |
|---|---|---|---|
| | | | const UChar g_aucIntraModeBitsAng[7] = {2, // 2x2<br>5, // 4x4<br>5, // 8x8<br>5, // 16x16<br>5, // 32x32<br>3, // 64x64<br>3 // 128x128}; |
| **Rotational transform (ROT)** | Enabled | Disabled | ROT : 0 |
| **Mode depend. directional transform (MDDT)** | Enabled | Disabled | #define QC_MDDT 0 |
| **Adaptive Intra Smoothing (AIS) on/off** | Enabled | Disabled | AIS : 0 |
| **Combined Intra Prediction (CIP)** | Enabled | Disabled | CIP : 0 |
| **Planar prediction** | *Enabled* | *Disabled* | *#define PLANAR_INTRA 0* |
| **Edge-based prediction** | Enabled | Disabled | EdgePredictionEnable : 0 |
| **Deblocking filter** | Enabled | Same as B300 | Same as B300 |
| **Adaptive loop filter (ALF)** | Diamond | Same as B300 | Same as B300 |
| **Entropy coder** | *PIPE* | *Same as B300 or CABAC* | *Same as B300* |
| **Transform coefficient coding** | HHI | Same as B300 | Same as B300 |
| **Internal Bit-Depth Increase (IBDI)** | 4 bits | Same as B300 | Same as B300 |
| **Rate Distortion Optimized Quantization (RDOQ)** | On (non-norm) | Same as B300 (non-norm) | Same as B300 |
| **CABAC-based RDO** | On (non-norm) | Same as B300 (non-norm) | Same as B300 |
| **Asymmetric Motion Prediction Unit (AMP)** | Enabled | Disabled | AMP: 0 |
| **Block Merging (MRG)** | Enabled | Disabled | MRG: 0 |
| **Motion vector prediction (AMVP/IMVP)** | AMVP method | Same as B300 | Same as B300 |



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| | | | |
|---|---|---|---|
| **Interpolation filter** | *SIFO* | *DCT-IF 12 tap* | *InterpFilterType: 0*<br>*DIFTap: 12* |
| **Adaptive motion vector resolution (AMVRES)** | Enabled | Disabled | AMVRES : 0 |
| **Transform Skip Flag** | *Disabled* | *Same as B300* | *Same as B300* |
| **PU-Based Merging** | Disabled | Same as B300 | Same as B300 |
| **Partition-based intensity compensation** | Disabled | Same as B300 | Same as B300 |
| **Transform precision extension** | Enabled | Disabled | undefine TRANS_PRECISION_EXT |

The LC variation proposed in the contribution is shown as follows (showing only the rows that differ with the HE variation shown above), with topics identified as open during the discussion being shown in italic font:

| **Tool name** | **TMuC default setting (JCTVC-B300)** | **Proposed setting** | **Parameters for proposed setting** |
|---|---|---|---|
| **Adaptive loop filter (ALF)** | Disabled | Same as B300 | Same as B300 |
| **Entropy coder** | LCEC | Same as B300 | Same as B300 |
| **Internal Bit-Depth Increase (IBDI)** | Off | Same as B300 | Same as B300 |
| **CABAC-based RDO** | *Off (non-norm)* | *Same as B300 (non-norm)* | *Same as B300* |
| **Interpolation filter** | *DIF* | *DCT-IF 6 tap* | *InterpFilterType: 0*<br>*DIFTap: 6* |
| **Adaptive motion vector resolution (AMVRES)** | Disabled | Same as B300 | Same as B300 |
| **LCEC Phase 2** | Disabled | Enabled | #define LCEC_PHASE2 (1) |
| **Transform precision extension** | Enabled | Same as B300 | Same as B300 |
| **Shift bits for transform precision extension** | 8x8: 7 bit<br>16x16: 6 bit<br>32x32: 5 bit<br>64x64: 4 bit | 8x8: 4 bit<br>16x16: 4 bit<br>32x32: 4 bit<br>64x64: 4 bit | const int g_iShift8x8 = 4;<br>const int g_iShift16x16 = 4;<br>const int g_iShift32x32 = 4;<br>const int g_iShift64x64 = 4; |

Some particular other subjects of discussion not shown in the table above were recorded as follows:

- CU-based merging / MRG – harmonization with skip/direct
- PU-based merging – not included



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- Bidirectional rounding control

**JCTVC-C066 Cross verification of Mitsubishi 0.7.4 configuration [M. Zhou (TI)]**

This document reported cross-check results of the simplified TMuC-0.7.4 configurations proposed in JCTVC-C122. Independent simulations were reported to have verified that the results that Mitsubishi provided for JCTVC-C122 were accurate.

**JCTVC-C065 Testing results on the simplified TMuC configurations [M. Zhou (TI)]**

This document reported evaluation results of simplified TMuC0.7.4 configurations, the tools included in the simplified configurations are identical to the ones proposed in JCTVC-C122, with the exception that the CABAC instead of PIPE is used in the HE configurations and 12-tap instead of 6-tap DCT-IF is used for the LC configurations. Also tested was the performance of the DCT-IF with different filter lengths (6, 8, 10, and 12) under the simplified configurations. The contributor recommended to use CABAC in the HE reference configurations due to an expressed uncertainty of the PIPE development for throughput improvement purposes, and considering 8-tap DCT-IF for both the HE and LC reference configurations. In terms of compression performance, using CABAC rather than PIPE was asserted to provide some slight (0.1-0.3%) improvement, and additional improvement (3% in random access and 4% in low delay) was reported for LC configurations by using longer DCT-IF (8 or 12 tap rather than 6 tap).

**JCTVC-C269 A study on the impact of intra smoothing [A. Tabatabai, C. Auyeung, T. Suzuki (Sony)]**

This contribution discussed the effect of disabling intra smoothing for the suggested HEVC Test Model in JCTVC-C122. The "always off" setting was reported to be better than always smoothing by about 1.4% for Intra HE, and 1.9% for Intra LC, with respect to the results in JCTVC-C122 with PIPE. Cross verification of the results was reportedly done with NEC.

This was tested in the context of the configuration suggested in JCTVC-C122.

It was noted that a late input contribution JCTVC-C302 was a new proposal with some relationship to this.

**JCTVC-C123 On selecting coding tools for HEVC test model [K. Sugimoto, A. Minezawa, S. Sekiguchi (Mitsubishi Electric)]**

As the result of test model discussion in the last (Geneva) meeting, the group agreed to define an HEVC Test Model with a minimum set of coding tools consisting of those that can jointly provide sufficient coding gain. This contribution discussed the selection of tools for the HM to create a reliable starting point for the the future standard.

Some remarks and observations made during the discussion of the contribution were as follows:

- LCEC Phase 1 was suggested to have some problems. (This may have been related to the issue fixed in TMuC 0.7.4.)
- Interpolation filter length was suggested to be studied.
- Some coding tools seemed to have different effects on different video resolutions.
- It was suggested to pay attention to complexity issues.

**Further discussion on TM definition**

- RQT :
    - HE: 3-level QT and fast intra encode per JCTVC-C311
      Encoder settings:
      HHI_RQT_INTRA_SPEEDUP_MOD = 0 with



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HHI_RQT_INTRA_SPEEDUP = 1
(slower search should remain configurable in the software)

  - LC: 2-level QT, aligned with LCEC Phase 2 (with QCOM CBP VLC), with same fast intra.
  - Same maximum QT depth for luma and chroma.
  - Clear description of this was to be provided as a BoG report document JCTVC-C319 by the 1st half of morning of Thursday, with its preparation coordinated by Thomas Wiegand. This was done and the result was reviewed and adopted as recorded below.

- Entropy coder (CA)PIPE or CABAC
  - Entropy coding is a core part and should not be exchanged arbitrarily; however, both of these technologies are using same context modeling and are almost identical in performance, and the choice does not affect other tools (PIPE 0.1-0.3% BR increase).
  - Complexity advantage of PIPE is not clear.
  - It was agreed that the TM would use CABAC rather than PIPE, further investigation (AHG, CE) was planned on PIPE.
- Max. 17 vs. 34 intra directions – it was agreed to keep it for the TM of this meeting as it is in current configuration of JCTVC-B300 (maximum set of 34 directions), and to set up an experiment for further investigation.
- AIS – settled: this will be turned off in the TM / WD
- Planar Prediction:
  - There is a slight loss in BD BR, but some experts think that this could improve subjective quality.
  - The current TMuC does not have encoder decisions based on subjective quality.
  - Conclusion: Not in TM, further study should be performed.
- Interpolation filters

  Suggestions made:

  a) For LC SIFO 6-tap, for HE SIFO 8/12-tap

  b) For LC DCT-IF 6-tap, for HE DCT-IF 12-tap

  c) DCT-IF 8-tap for both cases

  d) For LC DIF, for HE DCT-IF 8-tap

  e) For LC SIFO 6-tap, for HE DCT-IF 12-tap

  For HE: DCT-IF 12-tap was reported to give the best quality – and its use was agreed.

  For LC: DIF

  Chroma interpolation will be further investigated in a CE

  At the close of the meeting, the decision on chroma interpolation remained somewhat unclear, and an email discussion was conducted to clarify the situation. Within approximately two weeks of the meeting, this discussion closed with an agreement to use bilinear 1/8th sample interpolation for the TM / WD chroma interpolation.

  More detailed remarks and notes are provided below to show some background for the above decisions:



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- The number of filter tap operations of 6-tap DIF vs. 6-tap separable is roughly 60% both for average and worst case.
- The encoder complexity of SIFO appears higher (reported as about 30-70% computation time increase at encoder). In current optimization, all filter types are checked during encoding to determine the best filter for the next frame.
- SIFO also requires a larger set of filters.
- As a first conclusion, SIFO was removed from the list of candidates.
- According to encoder/decoder computation times, DIF and DCT/IF 6tap appear quite close.
- In the number of tap operations, DIF needs less (see above).
- DIF also needs lower bit depth.
- DCT-IF provides 1.8% BR reduction.
- If IF takes 30% of decoder time, and DIF would reduce from 100 to 60, this would come to 0.6x30 approx. 15% of entire decoder time. Realistic may be 8%.
- Agreement: use DIF – CE/AHG to further investigate.

- Bidirectional rounding control should be included.

**JCTVC-C319 BoG report: residual quadtree structure [T. Wiegand, H. Schwarz, B. Bross (Fraunhofer HHI), A. Fuldseth (Cisco), X. Wang (Qualcomm), W.-J. Han (Samsung)]**

This document contained the report of the break-out group on residual quadtree structure.

Some concern was expressed that the document did not contain sufficient informative description, and backgroun information was explained verbally during the discussion and was then added in a revision.

Decision: Adopted.

## *15.3 Test model design: non-normative aspects and test methodology*

**JCTVC-C253 Encoder speedup for bidirectional averaging with rounding control [R. Panchal, M. Karczewicz, P. Chen (Qualcomm)]**

In the 2nd JCT-VC meeting, bidirectional averaging with rounding control (BiRound) was proposed and adopted in the TMuC. In this contribution further encoder optimizations were proposed leading to a reported 50% complexity reduction of the BiRound with no changes in the encoder bitstream.

In TMuC 0.8, a new function with 'BiRound' parameter is always used for bidirectional motion estimation. To achieve further speedup, the new function is used only when 'BiRound' parameter is 1. Otherwise, the original function is used.

Results were provided with LD HE configuration. The old version as implemented in TMuC 0.7 showed an increase in encoding time by 8% and 1.1% BR reduction, a speedup which produces bit-exact result is reported with 4% increase, and a sub-optimum speedup gives 0.9% reduction with no change.

Conclusion:

- Decision: Adopted.
- Should be on when IBDI is off and vice versa.
- The fast bit-exact version shall be used in the encoder.



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**JCTVC-C287 Cross-check of encoder speedup for bidirectional averaging with rounding control [B. Bross (Fraunhofer HHI)] (missing prior, available first day)**

This contribution confirmed the bit rate results reported in JCTVC-C253, with the reported encoder speedup being slightly better.

**JCTVC-C315 On the computation of PSNR and BD-Rate [D. Hoang (Zenverge)] (late reg.)**

This late contribution was not reviewed in group discussion due to lack of time.

The contribution asserted that the computations of PSNR and BD-Rate by the current TMuC software and spreadsheet macros were flawed, and recommendations were made on how to improve these computations.

# 16 TMuC settings and common test conditions

**JCTVC-C084 Coding efficiency report of modification by TMuC draft005 [T. Yamakage, T. Chujoh, T. Watanabe (Toshiba)]**

This contribution showed experimental results of the modification by TMuC draft005 that signals the ALF filtering control map in the slice header instead of signaling it in the CU header. Experimental results reportedly showed that the coding efficiency loss is 0.04% on average while the interleaving process of the ALF filtering control map at encoder side is removed.

This was one of the features of "TMuC low priority" disabled by default (only implemented after TMuC 0.7)

Several experts pointed out that this proposal simplifies the encoder (no buffering of encoded data).

Decision: There was no objection by the group, and it was agreed to Adopt this proposal.

One expert points out that there might be other ways to achieve this goal.

**JCTVC-C243 Cross check result of JCTVC-C084 [I. S. Chong, M. Karczewicz (Qualcomm)] (missing prior, uploaded substantially after the meeting)**

This contribution was verbally presented prior to upload. It reportedly confirmed the results reported in JCTVC-C084.

**JCTVC-C155 TMuC 0.7 results with sequence dependent QPs [K. Andersson, R. Sjöberg (Ericsson)]**

This contribution investigated performance when targeting CfP bit rates using sequence specific QPs rather than those specified in the common conditions (QP=22, 27, 32 and 37) for low delay and random access configurations. The sequence specific QPs was asserted to give very similar coding efficiency as for the common conditions and to give bit rates generally closer to application bit rates and thus to be better suited for subjective assessment. It was noted that the worst case encoding time was reduced by about 20% when using the proposed alternative values.

The following remarks were recorded in discussion of this contribution:

- Typically, the example QP settings suggested have a much lower range of operational points – would this really be desirable?
- Some cases go into the low-quality range particularly.
- No action was taken on this, as the current settings seem appropriate for investigation of the merit of single coding tools.



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**JCTVC-C168 Comments on common test conditions [K. Kondo, K. Sato, T. Suzuki (Sony)]**

This contribution proposed to change the test conditions as follows.

- To reduce the number of frames
- To increase the number of test sequences

The common conditions test configurations were summarized in JCTVC-B300. Currently test sequences used by CfP are used and all frames must be encoded. Coding performance results with a smaller number of frames, e.g. 120, were reported to be not so different from the results of using all frames. Instead of reducing the number of total coded frames, it was proposed to test a larger variety of test sequences, e.g. VCEG test sequences, 4K sequence, 8K sequences, etc. To test a variety of test sequences was asserted to be more helpful to achieve an understanding of the the coding performance rather than encoding a larger number of frames in a smaller number sequences.

Comments recorded during the discussion were as follows:

- Subjective tests should also be performed, such that long sequences are needed.
- Extending the test set to provide more variety appears useful, but needs careful study.
- Having long sequences is also an advantage, as it enforces to not use overly complex methods – with parallel processing, the length of the sequences is the main bottleneck anyway.
- For extreme resolutions, a shorter length may be considered.
- Work on fast motion estimation should be started.
- It was suggested to conduct further study in an AHG (chaired by T. Suzuki)

# 17 Application-specific topics

**JCTVC-C021 Evaluation result of JCTVC-B031 [K. Kazui, J. Koyama, A. Nakagawa (Fujitsu)]**

A scheme which reportedly minimizes the loss of coding efficiency in very low delay coding was proposed at the 2nd JCT-VC meeting. This contribution shows evaluation result of the proposed scheme using TMuC software version 0.7.3.

Coding gains from the conventional multiple slices scheme in BD-Bit rate were reported as 9.0% and 15.9% when the sizes of LCTB are 64x64 and 32x32, respectively.

In addition, a new buffer model for a coding delay of less than one frame period was proposed in this contribution.

Remarks recorded during the discussion included the following:

- A very high number of slices was used per frame – is this realistic? Certainly other solutions would be possible to achieve the same goal.
- Constant bit rate was assumed for each slice – is that realistic?
- It was suggested to contribute software to the work of AHG on slices.
- Further study was encouraged.

**JCTVC-C032 Characteristics of Super Hi-Vision test sequences [Y. Shishikui, Y. Matsuo, A. Ichigaya, K. Iguchi, S. Sakaida (NHK)]**

This contribution presented the characteristics of Super Hi-Vision (SHV) test sequences, which reportedly differ from those of the other test sequences. The analysis of test sequences indicated that SHV test sequences contain an extremely large amount of motion that affects spectrum characteristics of the signal



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to a large extent. SHV test signals also contain a larger noise component due to their high bandwidth, although this does not affect subjective picture quality as much as was expected by the objective amount.

The Sequences were interpolated by Bayer filter to achieve a full 8Kx4K resolution, and spectral characteristics are different from the 2K and 4K sequences (high flat-spectrum noise component appears to be present below quarter of sampling frequency).

**JCTVC-C055 Performance report of TMuC for Super Hi-Vision [K. Iguchi, A. Ichigaya, Y. Shishikui(NHK), S. Sekiguchi, A. Minezawa (Mitsubishi Electric)]**

This contribution reported the performance of TMuC 0.7.0 for Super Hi-Vision (SHV) sequences. While the TMuC achieved substantial coding gain relative to the AVC CfP anchor, it took from 3.1 to 6.1 times encoding time than JM encoding with CfP anchor condition.

The following remarks and observations were recorded:

- There was a suggestion that cropped sequences could be used that would give roughly same results with much lower simulation time.
- BD bit rate improvement is approx. 60% for Steam Locomotive, 40% for Nebuta
- PSNR curves show larger gap (higher gain) towards higher bit rates: Does the TMuC loop filter improve prediction under noisy conditions?
- Bit rates ranged from 500 Mbps to 1.5 Gbps, PSNR 30-37 dB
- 10 bit to 8 bit conversion was done by rounding
- True 8K sequences (not upsampled) would be desirable to judge without influence of the upsampling filter.

**JCTVC-C276 Screen content coding results using TMuC [C. Lan, J. Xu, F. Wu (Microsoft), G. Shi (Xidian Univ.)]**

New coding tools had been presented for coding screen contents using an AVC framework in JCTVC-B084. This document presented new coding results using the TMuC, for intra coding and for random-access cases.

The following remarks and observations were recorded during the discussion:

- Recorded at 10 fps
- BD rate saving around 20% for random access inter, 28% for all intra.
- More information about the characteristics of these sequences was requested – e.g., How often do frame changes occur, is there subpixel motion?
- What would be typical test material? This may be the most difficult issue, as this has high influence on potential selection of tools.
- As this is a new application area, the importance should be reviewed by the parent bodies.
- Video (particularly news) includes lot of this type of content nowadays.



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# 18 Non-TE Technical Contributions

## *18.1 Loop filtering*

**JCTVC-C085 Comparison of loop & post filtering for in-loop and post-processing filtering AHG [T. Yamakage, T. Chujoh, T. Watanabe (Toshiba)]**

This contribution showed experimental results of comparison between in-loop filtering and post filtering. This was a response to one of the mandates of the In-loop and post-processing filtering AHG. Coding efficiency of several filtering schemes was compared for in-loop or post filtering and discussed.

Remarks recorded included the following:

- The current QC_ALF of the TMuC performs 4% better than a similar stand-alone post-filter
- The method from AVC (SEI) AAPF performs 2.5% worse than QC_ALF (an amount which slightly decreases when operated in the loop)
- Results also reportedly show that a filter must be explicitly designed as a loop filter or post filter

**JCTVC-C113 Adaptive loop filter with low encoder complexity [I.S. Chong, W. Chien, M. Karczewicz (Qualcomm)]**

In this contribution, low complexity versions of the Adaptive Loop Filter (ALF) with at most two encoding passes were proposed. Simulation results for one-pass and two-pass ALF are presented to demonstrate that one-pass and two-pass methods significantly lower the complexity of the original ALF with small performance degradation (less than 0.1% for two-pass and less than 0.7% for one-pass).

- The one-pass method derives the map by using a filter from the previous frame and then optimizing coefficients for the current frame based on regions where the filter is switched on.
- A two-pass method with one more iteration was described
- A post filter from the VCEG KTA software was also compared (losing 0.9% BR relative to the anchor)
- The method is very similar to the one proposed in JCTVC-C082

**JCTVC-C195 An enhanced block-based adaptive loop filter in TMuC0.7.0 platform [P. Wu, S. Paschalakis, N. Sprljan (Mitsubishi Electric)]**

In this contribution an Enhanced Block-based Adaptive Loop Filter (EBALF) algorithm has been implemented and integrated into TMuC0.7.0 platform as a complete functional block for in-loop filtering processing. Without altering the current default adaptive loop filter technology, which is contributed by Qualcomm as QC_ALF in the TMuC software, this EBALF functional block can be placed before or after QC_ALF, resulting in an in-loop filtering composed of two stages. The simulation results reportedly confirmed that with QC_ALF "on" performance as the reference point, the joint filtering can potentially further improve the coding efficiency by *up to* 1.5% BD rate reduction *in some cases*. For Class A tests, the average BD rate reduction were 0.7% and 0.6% in both test cases. This could reportedly imply that performance of QC_ALF can be improved further, particularly for high resolution sequences. The simulation results cover encoder_randomaccess and encoder_lowdelay configuration settings with full length and all classes of the sequences as defined in the Tool Experiment 10 subtest 2 category. The Excel spreadsheet results were provided. This contribution was reportedly not intended to propose an alternative technology to replace QC_ALF in TMuC but rather to be aiming to assist the current general effort on evaluating the existing TMuC video coding tools, such as that in Tool Experiment 12 (TE12) and 10 (TE10). The results reported independently in this document regarding the adaptive loop filtering technology can be treated as additional information to all other related test results in TE12 and TE10.



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It was remarked that a gain (0.6-0.7% BR reduction) was achieved only for class A and B partially, and that on average there was practically no gain. Decoder runtime increases by 15-20%.

No action was taken in response.

**JCTVC-C211 Inner block oriented ALF processing for memory & bandwidth reduction [Y. Sohn, K.-H. Lee, B.-K. Lee, I.-K. Kim (Samsung)]**

This proposal described an adaptive loop filter that was asserted to have low memory, bandwidth and computational complexity requirements. ALF in TMuC requires spatial neighboring reconstructed data for CU based ALF processing. This document proposes applying filtering only to a restricted inner LCU area where there is no need to use data outside of the LCU for filtering. This approach was reported to result in marginal performance degradation with memory, bandwidth and computational complexity reduction. The experimental results reportedly showed 1.0% performance degradation in low delay configuration and 0.8% performance degradation in random access configuration, respectively. In expense of this performance degradation, it was asserted to reduce about 24 Kbytes external DDR memory and 0.77 Kbytes internal SRAM, and to reduce memory bandwidth about 5.98 MHz in the case of 4Kx2K@30p video sequence and 64 bit BUS. It was asserted to also reduce computational complexity for ALF processing itself.

Concern was expressed that for two adjacent filtered blocks, boundary effects may occur.

This would need to be a normative decoder issue (making it switchable would not help to reduce maximum decoder complexity). Most experts believed that not every application case of loop filtering would benefit from that.

A suggestion by the chair was that if limitation of memory accesses is desired, it might be better to limit the number of filtered blocks in a profile.

**JCTVC-C219 In-loop reference frame denoising [P. Amon, A. Hutter, E. Wige, A. Kaup (Siemens)]**

This proposal presented 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 affect the inter frame prediction. For noise filtering of the reference frame, a denoising algorithm is implemented inside the AVC reference software JM 15.1. It was reported that the bit rate can be decreased for (high resolution) noisy image sequences especially for higher qualities at medium to high data-rates.

The following remarks were recorded:

- The suggestion was to take into account additive noise in the design of the filter coefficients.
- The implementation was in the AVC context.
- The algorithm currently does not work on intra.
- It is not necessary to transmit filter parameters; as these are estimated at the decoder.
- The reported improvement was mostly at high bit rates, and may be hardly visible.
- The concept may eventually help for applications that require lossless or near-lossless coding (e.g. medical, studio).
- The algorithm does not remove quantization noise. It is more intended to separate content that is consistent over time from noise that is uncorrelated between frames and therefore disturbs the prediction. At low rates, it was suggested that this would be removed anyway by the quantization.
- Further study was suggested.



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## *18.2 Block structures and partitioning*

**JCTVC-C025 CTB splitting on frame boundary for arbitrary resolution video [F. Yang, W. Li, S. Wan, Y. Chang (Xi'dian Univ.)]**

The conception of CTB has been proposed. But the modes of the CTB on the frame boundary may be limited when the video resolution is not an integral multiple of the LCTB. A method of CTB splitting on the frame boundary for arbitrary resolution video was proposed in this document, where the non-square CTB and a new representation of the CTB mode reportedly significantly contribute to the coding efficiency. The proposed method was asserted to be compatible with the current TmuC, with no extra syntax needed. Remarks recorded during discussion were:

- Largest gain comes from small image sizes, for classes other than D typically around 0.1 percent, but would require considerable change of CB design.
- Adds irregularity to the CTB, which makes it necessary to augment the parsing of the tree by additional conditions that depend on frame size.
- No action taken.

**JCTVC-C026 Proposal of frame parameters FLCTB and FSCTB for video content fitting [F. Yang, W. Li, S. Wan , Y. Chang (Xi'dian Univ.)]**

The size of CTBs in a frame in the TmuC is limited by the parameters of LCTB and SCTB, which are set on the sequence level. However, the optimal CTB splitting mode for a frame depends on the frame content, the frame type, and the quantization parameter, which indicates that different LCTB and SCTB should be used for different frames. Therefore, two frame parameters of FLCTB and FSCTB were proposed to adapt CTB splitting to the frame content. Remarks recorded during discussion were:

- No results available yet
- There is some doubt that this provides gain.
- No action taken.

**JCTVC-C154 Fine granularity slices [R. Sjöberg, P. Wennersten (Ericsson)]**

In order to increase the granularity of possible slice boundary positions this contribution proposed to change the definition of slices from being a sequence of largest coding tree blocks (LCTB:s) to a sequence of the smallest coding tree blocks (SCTBs) in order to increase the control of the slice sizes in terms of bytes.

This contribution also contained a proposal to replace UVLC for signaling of slice start positions with a fixed length code (FLC) with a one-bit shortcut for indicating the first block in a picture since this address is present in all pictures. Remarks were recorded in discussion as follows:

- Applications of slice-wise processing are parallelization for UHD (where the current design is not a problem) and packetization in videoconferencing.
- In terms of coding efficiency, the main disadvantage of slice-wise processing is the breaking of prediction chain and entropy coder adaptation.
- The main argument for change of CTB signaling would be a more clean design.
- Conclusions:
    - Regarding the slice processing, defining slices as sequence of largest CU give a disadvantage in regard to flexibility.
    - An estimate of solving the problem by restricting to 32x32 slices (taken from TE12) points to 5% BR increase.



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- A suggested first step would be to start slice implementation (suggested for an AHG chaired by Rickard Sjöberg) with the current CU structure, and only after that further more concrete evidence can be collected

Another late "Proposal 3" was presented in the presentation slides (not in the contribution document). Slice implementation would appear to be more simple if the design would return to JCTVC-A205 draft 2 (min_coding_unit_size and hierarchy_depth); In fact it was suggested that the current syntax seems to be broken as it does not support rectangular CU (only square). It was suggested that this other proposal should be registered as a new document (first discussed with the TMuC editors).

**JCTVC-C318 TMuC text on max CU size seems broken [R. Sjöberg (Ericsson)] (late reg.)**

The issue reported in JCTVC-C318 was partially presented in the slide deck of JCTVC-C154, where it was called "proposal 4". The slide deck did not give very much information about the issue; and it was not in the word document and seemed to be somewhat independent, so it was suggested to register this as a separate input document. This document arrived quite late, and there was insufficient time for this late contribution to be reviewed.

It may be beneficial for the contribution to be studied by those with detailed knowledge about the tree implementation. The subject matter of the document at the close of the meeting may (or may not) be addressed by the breakout activity report in JCTVC-C319.

**JCTVC-C167 Proposal on large block structure and quantization [K. Sato (Sony)]**

For common test conditions in video codec standardization, the value of quantization parameter is usually fixed within a picture, or a sophisticated scheme like RDOQ is sometimes employed for coding efficiency improvement. However in the real applications, a QP-changing scheme with macroblock-by-macroblock variation of QP is usually employed for visual quality improvement (and rate buffer control).

Adaptive quantization as defined in MPEG-2 Test Model was suggested to be a very old technique but still one of the effective techniques for subjective quality optimization. It determines QP according to the activity calculated from the values of original samples within a macroblock. The basic concept is that human eyes are sensitive to degradation in flat areas, but insensitive to busy areas, so smaller QP is allocated for the former areas and bigger QPs are allocated for the latter areas. This was suggested to work effectively, especially when the size of the image is large (like HD). One of the key applications of HEVC will be beyond-HD image coding, so techniques like adaptive quantization seem likely to also be useful for HEVC.

The HEVC TMuC employs the concept of a coding unit (CU). The largest coding unit (LCU) corresponds to macroblock in the existing video coding standard like MPEG-2 or AVC. The main difference is that the size of the latter is fixed to 16x16 pixels while the one of the former can be up to 128x128. In the existing video coding standards, QP can be set at the macroblock-level.

However, as the size of LCU becomes large, it may contain both flat areas and busy areas, and if QP can only be set at LCU-level, such adaptive quantization may become more difficult.

Therefore it was proposed to define the CU syntax so that QP can be changed not only with LCU level but with all CU levels. This modification can enable QP changing for subjective quality and was asserted to be useful for real applications. Remarks recorded during the discussion included the following:

- More evidence would be necessary (e.g. demonstrating that the switching of QP at 16x16 blocks gives an advantage over switching at 64x64)
- What would be the bit rate increase if no switching is used? At least it would be necessary to have a syntax element e.g., at the picture or slice level to disable the encoding of cu_qp_delta.
- Further study was suggested.



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**JCTVC-C224 Frame coding in vertical raster scan order [D.-K. Kwon, H. Kim (TI)]**

In HEVC, the CUs (Coding Units) in a frame are encoded in a horizontal-first raster scan order. It was reported that the frame coding in this raster scan order is not always effective for intra prediction and requires large on-chip memory to cover large vertical motion for motion estimation (ME) and motion compensation (MC), which is very challenging especially for UHD (ultra high definition) video such as 4k x 2k and 8k x 4k. In this contribution, it was proposed to support frame coding in a vertical-first raster scan order along with the horizontal-first raster scan order. Then the best coding scan order could be selected adaptively for each frame based on coding efficiency, horizontal/vertical motion, on-chip memory saving, etc. Remarks recorded during the discussion included the following:

- Changing order (by rotating 90%) improves performance for some sequences by up to 3% , but nothing on average (i.e. loss for others).
- This introduces a 1 frame delay
- How would an encoder decide this?
- No action taken.

**JCTVC-C260 Flexible picture partitioning [K. Panusopone, X. Fang, L. Wang (Motorola)]**

This document proposed use of a 2D coordinate system to partition a picture into largest coding tree units (LCTU) in a more flexible manner. The 2D coordinate system plane is divided into square blocks by vertical and horizontal lines. The block size is the same as the selected LTCU size. The top-left corner of a picture may be aligned with the coordinate system origin, or shifted away from the coordinate origin by an offset. The picture partition follows the square blocks in the coordinate systems. Remarks recorded during the discussion were as follows:

- Alignment of CU grid by default in top-left; Corner mode allows one of 4 corners; explicit mode allows positioning of CU block grid with any offset
- Results were reported with 30 frame length sequences, coded as IPPP (not common conditions), with adaptations for each frame; and a gain was reported of 0.63% on average, the largest gain being in class E.
- These results were achieved by running 4 encodings with the 4 corner options and selecting the best. It was suggested that the 400% encoder complexity increase would certainly not be justified by the small gain.
- No action taken.

**JCTVC-C275 Improve intra frame coding by PU/TU reordering [X. Peng, J. Xu, F. Wu (Microsoft)]**

This document presented an adaptive PU/TU reordering scheme for prediction in TMuC intra-frame coding. Within a PU, the coding order of TUs was rearranged to achieve better prediction for the inner TUs. Within a CU, a different coding order of PU can be selected also to reportedly obtain a better prediction. Remarks included:

- The ordering is dependent on prediction direction.
- An increase in encoder runtime roughly to 170% was reported.
- The gain in bit rate for HE Intra was roughly 0.4%
- It is not clear how much of the gain comes from TU or PU re-ordering.
- No action taken.



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**JCTVC-C283 Region of block based dynamic video processing for HEVC [A. Paul (Hanyang Univ. / NCKU)]**

A region based adaptive video processing scheme based on SAD of macro blocks was proposed in this proposal. The average SAD of all the blocks in this region is calculated for computing a threshold value and thereafter this threshold value is used to adaptively select the search range. The proposed algorithm reportedly achieves 60% time reduction with negligible PSNR loss.

There was difficulty arranging presentation of this contribution and no action was taken on it.

**JCTVC-C306 Investigations for representing rectangular blocks using the merging concept [H. Schwarz, D. Marpe , T. Wiegand] (late reg.)**

This document investigated the impact on coding efficiency when the symmetric rectangular block modes (2NxN and Nx2N) were removed from the syntax and replaced by corresponding merge flags. For the same encoder complexity (given an algorithmic comparison and verified by the measurement of encoding times), an average increase in BD rate of 0.13% was reported for a removal of the symmetric rectangular blocks. A variation with lower encoding complexity (the average encoding time is 78% of that for the reference) reportedly yielded an increase in BD rate of 0.8%. If the encoder complexity is increased in comparison to the reference (the measured average encoding time is 144% of that for the reference), an average decrease in BD rate of 0.06% was reported. The following remarks were recorded during the discussion:

- This is one example about redundancy in the block structure (i.e. the same structure can be expressed in different ways).
- The current implementation of doing a full search on rectangular shapes may not be the best approach.
- It was suggested to establish an AHG to study the block structures (chairs WJ Han, TK Tan, T Wiegand)
- This should include intra & inter.

**JCTVC-C311 Fast intra encoding for fixed maximum depth of transform quadtree [B. Bross, H. Kirchhoffer , H. Schwarz , T. Wiegand (Fraunhofer HHI)] (late reg.)**

This document described an encoder-side complexity reduction for intra encoding. The presented fast encoding method produces bitstreams that are conforming to the specification while reportedly achieving a similar encoder complexity as for the transform quadtree disabled case.

Two fast modes had been implemented:

In speedup mode 1, the different intra prediction modes are tested only on the maximum allowed transform block size. The best performing mode is tested with the full transform tree partitioning and the best performing partitioning is chosen.

Speedup mode 2 does basically the same except testing the full transform tree partitioning with the two best performing intra modes instead of the best one.

Results were provided only for 50 frames of each sequence.

Mode 1: Enc. Time 101%, BR reduction 0.3%.

Mode 2: Enc. Time 120%, BR reduction 0.8%.

It was indicated that a new version with more additional results would be made available which shows also results with tree depth=2 which reports 0.1% and 0.3% BD BR gains for modes 1 and 2.

In addition, results were reported on disabling MDDT, ROT, edge pred and smoothing, with a degradation of 0.5% for mode 1 (96%/111% encoder for HE and LC), mode 2: 0.8%/0.2% for HE/LC with 116%/132% encoder time.



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**JCTVC-C312 Cross-verification of JCTVC-C311: Fast intra encoding for fixed maximum depth of transform quadtree [W.-J. Han (Samsung)] (late reg.)**

This late contribution reportedly confirmed the results of the original quadtree approach with 3 levels and the scheme described in JCTVC-C311, with computation times that differed slightly.

**Discussion on JCTVC-C311/JCTVC-C312**

The following remarks were recorded during the discussion of JCTVC-C311 and JCTVC-C312:

- Concern was expressed that for LC conf this may not give advantage.
- It was suggested to enable RQT only for HE mode, or to restrict it to a different depth for LC (possibility would be to restrict in LC depth=1 for intra, depth=2 for inter; depth=3 for both intra and inter in HE case).
- Note: depth=1 is said to be the same as RQT off for intra – this should be further verified.
- Note2: Using a different depth for inter and intra is currently not supported
- It was mentioned that the configurability that RQT provides has implications on other tools' performance. Therefore it would be important to have it in the TM.
- It could be studied in the context of the AHG on block structures + CE
- Definitely this needs to be further study in the AHG on block structures
- It was said that RQT on/off has implications on the choice of block sizes and modes for intra prediction (signaling is different and therefore other modes may be selected).
- From the software perspective, it would be undesirable to use the previous on/off version as these are completely independent paths
- A breakout group was formed to discuss the subject further, resulting in the BoG report JCTVC-C319 as discussed elsewhere in this report.

## *18.3 Motion compensation and interpolation filters*

**JCTVC-C126 Chroma interpolation filtering using high precision filter [D. Y. Kim, J. P. Kim, Y. L. Lee (Sejong University), J. Lim, J. Song (SKT)]**

In the TMuC, chroma interpolation is performed with the bilinear interpolation to obtain the 1/8-pixel vectors in the same way as in AVC. In this contribution, a chroma interpolation method using the 6-tap AVC luma MC interpolation filter with high precision was proposed. Experimental results reportedly show that the average BD-rate improvements on chroma U and V components are 12.2% and 13.4%, respectively, in the random access, low complexity case, and the average BD-rate improvements on U and V components were reported as 4.1% and 5.0%, respectively, in the random access, high efficiency case. The average BD-rate improvements on U and V components was reported as 12.0% and 14.9%, respectively, in the low delay, low complexity case, and the average BD-rate improvements on U and V components was reported as 2.0% and 2.4%, respectively, in the low delay, high efficiency case. The average BD-rate improvements on Luma were reported as 1.3% and 0.4%, respectively, in low complexity and high efficiency of the low delay case, and the average BD-rate improvements on Luma were reported as 0.2% and 0.4%, respectively, in low complexity and high efficiency of the random access case. Remarks recorded during the review included:

- The results are similar to what has been reported before in TE12 and other TEs.
- Establishing a CE on luma and chroma subpel interpolation was recommended
- It is still unclear what the real benefit in terms of overall BR gain is.



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- Complexity is certainly increased compared to bilinear interpolation.
- Subjective quality may also be an issue in this context.

**JCTVC-C137 Decoder-side block boundary decision (DBBD) with OBMC [S. Fukushima (JVC)]**

This proposal focused on the tool "Decoder-side Block Boundary Decision (DBBD)" which was proposed in JCTVC-A108 as one of tools for HEVC CfP response. DBBD aims to perform motion compensation with various block patterns without additional coding bits by deciding the MC boundary on the decoder-side. In this proposal, DBBD with OBMC was proposed for improving the quality of MC block in addition to the previous proposal. The simulation results reportedly show that the proposed technique provides 3.1% BD bit rate gain for random access, and 2.2% for low delay as against JM16.2 anchor under HEVC common test conditions. Remarks included the following:

- Only used in 16x8 and 8x16 modes
- Encoding time increased to roughly 400-500% (Currently ME is performed for every possible boundary position). Decoder time increased roughly by 10%
- AMP does something similar (with signaling), reducing the bit rate by roughly 2% but only increasing encoding time by 33%, with negligible decoder complexity impact.
- No action taken.

**JCTVC-C183 Enhanced switching of interpolation filter for HEVC [T. Yoshino, S. Naito, S. Sakazawa (KDDI)]**

Adaptive Interpolation Filter (AIF) technology (e.g., as in prior KTA work) has been proposed to improve the interpolation filter performance for fractional-pel motion compensation. However, this scheme requires high computational cost for calculating the filter coefficients on the encoder side. This contribution proposed an Enhanced Switch Interpolation Filter (ESIF) approach that pre-defines several interpolation filter coefficients in order to reduce the computational cost for calculating the coefficients. This scheme allows updating the number of filter coefficient sets and the filter coefficients slice by slice. The experimental results reportedly showed that the BD-bit rate against AVC reached 1.9% under CS2 condition. Remarks recorded during the discussion included the following:

- The Powerpoint presentation did not match with the contribution (a set of 8 filters was proposed instead of 4).
- The current scheme has 500% coder complexity.
- The "Low complexity scheme" with 130% coder complexity for filter decision gains 0.3-0.4% on average.
- No action taken.

**JCTVC-C204 Bi-directional optical flow [A. Alshin, E. Alshina (Samsung)] (missing prior, available first day)**

A modified B-slice prediction was proposed. By combining the optical flow concept and high accuracy gradients evaluation this proposed technique allows sample-wise refinement of motion. This approach does not require any signaling about motion vector refinement to the decoder.

- Sample-wise refinement is performed by solving optical flow equations between two reference images. For gradient calculation, DCT-based interpolation is used.
- Uses an anchor with both MRG and skip/direct and DCT-IF12 used for comparison
- The reported gain was roughly 2%, with decoder runtime roughly 150%
- It was suggested to include this in an experiment on decoder-side estimation



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**JCTVC-C215 Adaptive MV resolution with directional filters [K. Ugur, J. Lainema (Nokia)]**

This contribution presented an adaptive motion vector resolution concept using 1D directional filters. The goal of this contribution was to demonstrate the possible coding efficiency gains in interpolation with low complexity. It also presented a design of adaptive motion vector resolution in TMuC, with directional filters. Remarks recorded included the following:

- Saves computations at decoder through additional 8-pel positions (not a dense grid of all possible positions) which allows more 1D interpolations.
- Encoding time increased to 124% (due to additional search), decoding time decreased to 80% (although the time measurement results may not be reliable).
- Bit rate reduction was reported at 1.3% on average; where the gain comes due to additional 8$^{th}$ pel positions; and the gain was mostly in class D.
- Bilinear interpolation is used for chroma, whereas the LC version of TMuC may have a rounding problem; and it was suggested that this could explain part of the gain.
- It was suggested to study this further in the context of AMVRES and MC interpolation.

**JCTVC-C251 Overlapped block motion compensation in TMuC [P. Chen, R. Panchal, W.-J. Chien, M. Karczewicz (Qualcomm)]**

In this contribution, some results of overlapped block motion compensation (OBMC) in geometry partition coding were reported. The use of OBMC to asymmetric motion partitions was also proposed, with simulation results in support being presented. Remarks included the following:

- Is combined with geometric partitioning
- Geometric partitioning reportedly gives 3.9% BR reduction for RA, 3.6% for LD; and 0.8% of this is due to OBMC.
- If combined with AMP, the gain of OBMC is 0.4% and 0.3% for RA & LD, respectively.
- The increase of complexity at the decoder was asserted to be marginal.
- The presentation did not match with the available document, and it was indicated that a new version would be uploaded.

**JCTVC-C301 Geometry motion partition [P. Chen, L. Guo, M. Karczewicz (Qualcomm)] (late registration, missing prior, available first day)**

Geometry motion partition has been integrated into TMuC. The software implementation is based on the design proposed in JCTVC-A121. In the software, geometry motion partition is applied to CU size of 16x16 and 32x32. Geometry mode decision has two stages. First, fast geometry mode decision pre-selects 16 best modes based on SAD calculation. Then the best mode is selected based on full RD. Geometry modes are tested only if the best non-geometry mode is a non-skip mode. Remarks recorded included the following:

- For results, see above under JCTVC-C251
- Encoder runtime is 200%; geom. Partition test only done after skip decision.
- It was suggested to include this in a core experiment on asymmetric & geometric partitioning (previously in TE3).
- Note: checking of the sample membership to the left or right partition may also be of concern for complexity; if masks are used for that purpose, it should be considered that the number is low.
- The presentation did not match with the available document, and the contributor was requested to upload a new version.



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**JCTVC-C303 Geometry adaptive block partitioning (GEO) cross-check [E. Francois, P. Bordes (Technicolor)] (late registration, missing prior, available first day)**

This cross-check contribution reported exactly the same results in BR reduction as JCTVC-C301 (3 class B sequences were missing). No checking of runtime was reported.

**JCTVC-C254 Test result of SIFO for sequences with illumination change [R. Panchal, M. Karczewicz (Qualcomm)]**

SIFO was asserted to be not just an interpolation filter but it also to have the capability to compensate for illumination changes. SIFO results were provided for some sequences which had illumination changes to highlight that for such sequences, the offset component of SIFO provides useful gains. The test was done using TMuC 0.8 in the low delay configuration. Remarks recorded included the following:

- The presentation did not match with the available document, and uploading of a new version was requested.
- It was asked why should interpolation and illumination compensation be combined? It was suggested that these are two different issues (the latter also applying to full-pel positions). The answer by the proponents was that it would be possible to do it separately.

**JCTVC-C295 Re-compensation based on partial coefficients [H. Zhu (Zhu)] (late registration, missing prior)**

The proposal reportedly provided a new idea for video coding. The algorithm divides the quantized DCT coefficients to two parts, using the first part to get a first reconstruction, and using the first reconstruction R0 and the compensation signals Cmp0 and Cmp1 to compute a new weight for the motion compensation. No experiment results were provided, and no action was taken in response.

## *18.4 Motion vector coding*

**JCTVC-C208 Simulation results of motion partition, block merging and motion competition schemes [I.-K. Kim, T. Lee (Samsung)]**

In the current TMuC design, there are two approaches for frame partitioning: prediction unit (PU) splitting to make smaller motion partitions and block merging (MRG) to make larger motion partitions. In this proposal, anchor results are obtained by running TMuC-0.81 using reference configuration with disabling all motion partitions, motion competition and MRG. By enabling MRG on top of the anchor, improved BD bit rate is reported to be about 2.0% (random access), 0.2% (random access LC), 2.4% (low delay) and 0.0% (low delay LC). But higher BD bit rate savings can reportedly be obtained by enabling motion partition: 4.2% (random access), 5.8% (random access LC), 4.1% (low delay) and 5.1% (low delay LC). By enabling motion competition, improved BD bit rate savings are reported to be about 4.3% (random access), 5.6% (random access LC), 3.2% (low delay) and 5.2% (low delay LC). The best performance can reportedly be obtained by combining motion partitions and motion vector competition which shows 7.2% (random access), 9.2% (random access LC), 6.2% (low delay) and 8.3% (low delay LC) BD bit rate savings.

The results of TE12 were reported to have been confirmed.

**JCTVC-C257 On motion vector competition [Y. Su, A. Segall (SHARP)]**

A method was proposed to improve the performance of motion vector competition in applications that may experience errors during transmission. The focus of the contribution was the dependency between parsing and co-located motion vectors that is incorporated into the motion vector competition design. This dependency results in coding gain; however, it also results in an inability to parse a bit-stream if a previous frame is lost. To overcome this problem, it was proposed to send the motion vector candidate as a flag, which signals if the selected predictor is the temporal collocated block, and subsequently send an



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index into the set of spatial predictors when the temporal collocated block is not selected. Remarks recorded in the consideration of the contribution were as follows:

- This was presented near the end of the meeting, after difficulty coordinating a prior presentation time
- The goal is reduction of the buffer size; the advantage of robustness under loss was not proven yet.
- In the worst case the buffer is around 33% of a picture buffer in size.
- This may require computation of a median of 16 values, which adds complexity.
- A loss around 0.1% in bit rate was reported.
- It was suggested to include further investigation of this in a CE

## *18.5 B picture reference list redundancy*

**JCTVC-C278 Redundancy reduction in B-frame coding at temporal level zero [B. Li, J. Xu, G. J. Sullivan, F. Wu (Microsoft), H. Li (Univ. of Sci. &Tech. China)]**

In the current TMuC, the usage called GPB is widely used to replace a P slice with a B slice using two reference frame lists that contain the same pictures. As list 1 is identical to list 0, there is redundancy comparing using only list 0 with using only list 1 as references. This contribution suggested not to use list 1 prediction in this kind of B slice, restricting the available predictors to using bi-prediction and list 0 prediction. Compared to TMuC0.7 anchors, such a change reportedly leads to 0.1% bit rate savings for random-access cases and 0.9% bit-saving for low-delay cases, on average.

Encoding time was also decreased compared to the anchor (around 10%). See further notes regarding the JCTVC-C285.

**JCTVC-C285 Modified uni-directional inter prediction in generalized P and B pictures [W.-J. Chien, P. Chen, X. Wang, M. Karczewicz (Qualcomm)]**

This contribution proposed a modification of uni-directional inter-prediction in generalized P and B pictures (GPB). The modification restricts the reference list selection for uni-directional inter-prediction. Simulation results reportedly showed that 0.88% BD rate reduction can be achieved. The same method was proposed in JCTVC-C278.

It was remarked that the encoding time decrease is no argument, as this is implementation specific

At first it was suggested for an AHG to study this further and check the two methods, work out syntax and provide stable cross-checked software and results, and report about implications on the MMCO and RPLR

Decision: After further study and discussion, it was agreed that this seems to be quite simple to implement without complications (as confirmed by SW coordinator), and the proposal was adopted.

## *18.6 Quantization control*

**JCTVC-C135 Flexible scaling of quantization parameter [D. Hoang (Zenverge)]**

The current Test Model under Consideration (TMuC) employs a quantization parameter (QP) scaling that is borrowed from the AVC standard. 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, the contributor asserted that this 12.25% increment may be too coarse for certain applications, such as low-delay coding. This contribution proposed a specification that allows the granularity of the quantization parameter (QP) to be varied at the slice and picture levels.



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Backward-compatibility with the AVC approach is maintained at one of the granularity settings. In addition to varying the granularity, this contribution also proposed a variable QP offset that can be specified at the slice and picture levels.

It was remarked that there have been prior efforts to address the coarse quantization step size increment of AVC. In JCTVC-A114, the quantization step size was proposed to double every 16 increments of QP.

In AVC, the QP can vary from 0 to 51, inclusive (for 8 bit per sample coding). A full transition of QP from 0 to 51 reportedly translates to a 362-fold increase in the quantization step size. The contributor said that, in practice, only a small range of QP values are used when coding a scene at a given bit rate. It was also asserted that at scene changes, QP can change due to a change in scene complexity and then typically varies only slightly within a scene.

It was remarked that the complexity of supporting the proposed inverse quantization process in the decoder may not be trivial. It was suggested that dynamic range increase may be needed to obtain the suitable precision for frequency-specific norm adjustment, and that necessary LUT sizes and perhaps some other memory increase may be needed for the decoder to support this.

The relationship between luma and chroma quantization was also discussed.

It was noted that the stability of the transform design may not be at a stage where such a proposal would be timely.

Further study was encouraged.

## *18.7 Entropy coding*

### 18.7.1 Coefficient scanning and context selection

**JCTVC-C114 Zigzag scan for CABAC/PIPE [J. Lou, K. Panusopone, L. Wang (Motorola)] (missing prior, uploaded on first meeting day)**

In TMuC0.7, the macro "HHI_TRANSFORM_CODING" enables a set of transform coefficient coding tools. It is switched on by default when the entropy coding option is CABAC/PIPE. The set of transform coefficient coding tools is based on JCTVC-A116. Among these tools, an adaptive scan is applied for significance map coding. The contributor reported that experimental results indicate that this adaptive scan scheme achieves only a negligible performance gain, but introduces additional memory and computational complexity as comparing to the traditional zigzag scan. The contributor proposed to use a conventional zigzag scan rather than the adaptive scan for significance map coding when the macro "HHI_TRANSFORM_CODING" is switched on, or CABAC/PIPE is selected.

This topic was also discussed in the TE12 context – e.g., see section on JCTVC-C059.

The compression impact was estimated by the contributor was estimated here and in JCTVC-C059 as being in the range of 0.0 to 0.3%, depending on coding condition and test sequence class.

Further investigation of the topic was encouraged.

**JCTVC-C227 Parallelization of HHI_TRANSFORM_CODING [V. Sze, M. Budagavi (TI)]**

See also JCTVC-C059 and JCTVC-C114.

While various parallel bin encoding approaches have been proposed, context modeling remains a parallelism challenge in the entropy coding engine. HHI_TRANSFORM_CODING uses a highly adaptive context modeling approach for the coefficient significance map, where context selection depends on coefficients in neighboring positions. While it provides coding gains between 0.8% to 1.1%, it reportedly introduces significant dependencies which are difficult to parallelize when using zig-zag scan or adaptive scan order. In this document, the contributor proposed a "wavefront" diagonal scan order to enable parallel processing in conjunction with the use of the highly adaptive context selection for significance map. A simplification of the context selection was also proposed in the contribution. These



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modifications were reportedly implemented in TMuC-0.7.3 and the coding efficiency impact was reportedly evaluated. The modifications reportedly come at a cost of 0.2% to 0.4% coding loss. Despite this loss, the parallelized HHI_TRANSFORM_CODING with simplified context selection (reduce dependency by one or two scans) and wavefront scan (down left direction) was asserted to still provide gains between 0.9 to 1.4% when compared with not using HHI_TRANSFORM_CODING.

The contributor proposed conducting a CE/TE for further study of the topic.

**JCTVC-C205 Low-complexity adaptive coefficient scanning [V. Seregin, J. Chen (Samsung)]**

This contribution proposed a new scanning method for transform coefficients. It was proposed for the scanning mode for every Transform Unit (TU) to be defined explicitly based on RD estimation and a corresponding mode index signaled to the decoder. The proposed technique was tested relative to TMuC 0.7 and a comparison was made to the existing methods in TMuC 0.7. The performance was evaluated on 1 second duration sequences that were otherwise following based the common test conditions specified in JCTVC-B300 – the sequences were shortened to reduce the testing time. The proposed method reportedly provided 0.2-0.9% improvement for luma on average under HE conditions. In LC configurations the proposed method reportedly had similar performance as TMuC.

This would increase encoding complexity, to determine the selected scan order to be applied.

It was remarked that, instead of using syntax to indicate the scan order, the scan order could be inferred based on the intra prediction direction. Some proposals relating to this were also discussed at the meeting.

The contributor proposed conduction a CE/TE for further study of the topic.

**JCTVC-C250 Low complexity adaptive coefficient scanning [M. Coban, R. Joshi, M. Karczewicz (Qualcomm)]**

An adaptive coefficient scanning process is used to capture coefficient statistics based on the intra prediction mode. This contribution proposed to introduce a partial sort at the coefficient level for determining the scan pattern. The proposed scheme reportedly reduces the complexity of the existing adaptive coefficient scan algorithm, with a negligible average BD bit rate penalty.

If MDDT is disabled, the adaptive scan described in this contribution is not used. However, it could hypothetically be used without MDDT.

The contributor indicated that without MDDT, approximately 0.6% improvement under HE all-intra conditions, and 3% improvement under LC all-intra conditions was observed in some preliminary testing with short video sequences. The gain discussed for the LC case included another effect discussed in another contribution JCTVC-C263.

The proposed modification reportedly cuts the decoder run-time approximately in half.

Some of the results presented were not in the original contribution.

Some of the results had reportedly been cross-checked by RIM as reported in JCTVC-C307.

**JCTVC-C307 Cross Verification of Low Complexity Adaptive Coefficient Scanning [J. Zan , J. Meng , M. Towhidul Islam , D. He] (late reg.)**

This contribution reported cross verification results on "low complexity adaptive coefficient scanning" as described in JCTVC-C250. Due to limited time, RIM had only tested 5 sequences from each class; and for each test sequence, two QP values (22 and 37) for the "intra" and "intra-LC" modes.

The test results were compared with those from Qualcomm: 1) for the tests that macro "FAST_ADAPTIVE_SCAN" were enabled, both results reportedly matched on BD bit rate, and PSNRs on all test points; 2) for the tests that macro"FAST_ADAPTIVE_SCAN" were disabled, mismatches were reported between the results and those from Qualcomm except for the Class D sequences, although the difference was very minor (<0.1%).



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On decoding time, for the "intra LC" mode, an average of 43% decoding time was recorded on all available test points, and the Qualcomm data was an average of 37% on all QPs and all sequences; for the "intra" mode, an average of 60% decoding time was recorded on all available test points, and the Qualcomm data was an average of 51% on all QPs and all sequences.

It was noted that the tests could only be done on some selected sequences, with the lowest and highest QP values, due to time constraints. From the data collected on these test points, it was reportedly shown that the decoding time was greatly reduced.

This contribution was submitted late during the meeting, with very limited opportunity for review. It was not presented or discussed in detail.

## 18.7.2 LCEC modification proposals

**JCTVC-C263 Improvements on VLC [M. Karczewicz, W.-J. Chien, X. Wang (Qualcomm)]**

This contribution proposed changes relating to variable length coding (VLC) of transform coefficients, intra prediction modes, and inter modes. In this contribution, a modification was proposed to the current transform coefficient coding for intra blocks.

Coding schemes were also proposed for coding the prediction mode of both intra and inter blocks respectively. With a different VLC table selection method and different symbol combination, coding performance of the prediction modes was also proposed to be modified.

For LC all-intra, an average gain of 4.3% was reported, with MDDT disabled and ROT enabled. With ROT turned off, the contributor suggested that the gain would likely be similar.

For LC random access, an average gain of 3.2% was reported.

For LC low delay, an average gain of 2.4% was reported.

The results had not been cross verified.

Some complexity impact was reported due to the use of adaptive scanning.

The establishment of a core experiment on the subject was proposed (possibly split into different subject areas).

The LCEC coding in the TMuC software includes the coding of a terminating bit that is unnecessary and not described in the corresponding text. We agreed that this is considered a bug, and should be fixed. This somewhat affects the reported results, as noted by the contributor.

It was remarked that his has overlap with JCTVC-C185, and should be evaluated in the same CE/TE.

**JCTVC-C210 Efficient coefficient coding method for large transform in VLC mode [S. Lee, M.-S. Cheon, I.-K. Kim (Samsung)]**

This contribution presented a coefficient coding method for large transforms in LCEC mode. Tandberg, Ericsson, and Nokia's proposed coefficient coding method, which is reportedly currently implemented in the TMuC, was reportedly extended for the efficient coding of the coefficients from large transforms including 16x16, 32x32, and 64x64. Experimental results reportedly showed that the proposed method provides gain for random access and intra only configurations without a significant complexity increase.

For LC all-intra, an average 1.6% improvement was reported.

The results had not been cross verified.

**JCTVC-C152 Context-adaptive hybrid variable length coding [Y. Xu, J. Li, W. H. Chen, D. Tian (Cisco Systems)]**

This contribution presented a context-adaptive hybrid variable length coding method for entropy coding. This method is based on the reported observation that the non-zero transform coefficients are more



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clustered in the low frequency region while being more scattered in the high frequency region. The code tables are adaptively chosen based on the context information from coded neighboring blocks or from the coded portion of the current block.

The proposed algorithm was implemented and tested relative to JM 10.1 High Profile with fixed 8x8 transform size, and the simulation results were compared with CAVLC.

Further work would be needed to test the proposal in the TM design context to determine its applicability to the new design. The contributor indicated that such results may be available by the time of the next meeting.

## 18.7.3 V2V coding

**JCTVC-C279 Opportunistic parallel V2V decoding D. He, G. Korodi, E.-h. Yang, G. Martin-Cocher (RIM)**

A buffer-based technique that distributes codewords produced by V2V codes into interleaved fixed-length phrases was proposed. On the decoder side, since subsequent phrases can be accessed independently without waiting for the decoding of the current phrase to complete, an "opportunistic parallel decoding" can reportedly be achieved.

The proposal described the concept of this modified scheme. Some padding bits are needed at the end of the bitstream when applying this scheme. However, the scheme avoids the need for the pointers that are otherwise needed for identifying the location of the PIPE streams, and also avoids the bit-wise interleaving of the PIPE data.

A participant asked what length might be recommended for the "phrases", and the contributor suggested such examples as 16, 32, etc. (multiples of 8 bits).

It was suggested that some measurements of figures of merit for the technique should be presented.

Further study was encouraged.

## 18.7.4 Modified CABAC coding

**JCTVC-C296 Decoding improvement on the PA-Coder [H. Zhu (Zhu)] (late registration, missing prior, available first day)**

The contribution proposed a fast channel for MPS decoding of the PA-coder previously proposed in JCTVC-A027. Once a new bit is decoded, a threshold value is computed using a table lookup in the previous design. The threshold value is compared with the current value to decide the MPS or LPS.

The PA arithmetic coder was described as having reduced computational resource requirements relative to CABAC and PIPE, with slightly less compression capability.

The PA coder had been integrated into the JM, and the contributor indicated that integration of the coder with the TMuC software was reportedly expected to be completed soon. No action was taken in response to the contribution.

**JCTVC-C300 High-efficiency entropy coding simplifications [V. Sze , M. Budagavi (TI)] (late registration, missing prior)**

PIPE was described as a bin-level tool aimed to improve throughput by using 12 bin encoders in parallel. Binary symbols (bins) are assigned to each of the bin encoders depending on their probabilities; with the bins of different probabilities being processed in parallel. The contributor asserted that there is a large complexity (i.e. area cost) associated with the PIPE implementation due to the use of V2V (variable length codes to variable length codes) for the bin encoder, with an estimated area over 5x larger than CABAC. In this document, a multi-CABAC approach was proposed using a simplified binary arithmetic coding engine with quantized rLPS tables for the bin encoder to reduce complexity. The resulting area



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savings was estimated to be over 7x. The parallelism across bin encoders is still maintained, thus providing improved throughput at the bin level. The coding efficiency of TMuC-0.7.3 with the modified multi-CABAC and quantized rLPS tables was reported to have a 0.0-0.1% coding gain over PIPE.

The contributor indicated that the buffering associated with the probability interval partitioning remains a challenge in the proposed design.

A participant commented that CABAC power consumption could be an issue in such a design.

The fact that the probability estimate is static for each BAC decoder would substantially simplify the BAC engine operation.

The compatibility of the scheme in regard to the "load balancing" scheme found in the TMuC would need to be studied.

It was asked how to properly measure area, power, throughput, the difficulty of implementation in software, and, when comparing to LCEC, also coding efficiency.

Further study was encouraged.

**JCTVC-C304 Showing the possibility of fast CABAC [H.-J. Kim , X. Qu , W.-J. Han] (late registration, missing prior, provided later during the meeting)**

This late document was initially uploaded as an empty file. It was remarked that it had a confusing IPR statement, and it was indicated that a new version would be provided. Due to lateness, there was limited opportunity for its review. It described a proposed entropy coding method that was asserted to have lower complexity than CABAC. Results were reported on some test sequences. A 2-6% bit rate increase was reported along with a reported complexity reduction by 30-35%. No action was taken in response.

## 18.7.5 Entropy slices

**JCTVC-C256 New results for entropy slices for highly parallel coding [K. Misra, J. Zhao, A. Segall (SHARP)]**

The concept of an Entropy Slice was previously proposed for the HEVC design. Entropy slices enable separate definitions for neighborhood in the entropy decoding and reconstruction loops. Motivations for entropy slices were described. As a first benefit, it was asserted that the system enables parallel decoding with negligible overhead. This includes both the context adaptation and bin coding stages, and it is compatible with all of the entropy coding engines currently in the TMuC. As a second benefit, it was asserted that the degree of parallelization is flexible – an encoder may generate a bitstream that supports a wide range of decoder parallelization factors without knowledge of the target platform. As a third benefit, it was asserted that the entropy slice concept enables more meaningful profile and level definitions in terms of the impact on entropy coding. Specifically, profiles/levels can include limits that are relevant to the operation of the entropy coding component. This was asserted to be useful for all applications, but with a significant benefit to emerging, higher rate and higher resolution scenarios. The document provided some experiment results for entropy slices. Software is also provided in the contribution.

The proposal discussed the ability to initialize the state of the entropy coder either using syntax (e.g., cabac_init_idc) or using the end state from some other entropy slice. It was remarked that storing the end state from a preceding slice has a memory impact.

"Wavefront" processing operation had been suggested – and a straightforward method of providing this capability was described.

The basic concept of desiring enhanced high-level parallelism of the entropy coding stage to be in the HEVC design is agreed (as recorded in the Geneva meeting report).

It was remarked that the need to store the parsing results prior to completing some of the decoding process for the picture will have an impact on memory and memory bandwidth, and that this could be a serious concern.



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The overhead bits for indicating the location of the wavefront parallelism entry points were not accounted for in the coding efficiency experiment results.

It was remarked that, for coded frames that are relatively small, this overhead could be a substantial percentage of the data.

We can test coding efficiency impact, including overhead bits, and including comparison to regular slices.

Further study was encouraged (AHG or CE).

## *18.8 Intra prediction*

**JCTVC-C040 Chroma intra prediction using reconstructed luma [C. Yeo, Y. H. Tan, Z. Li, S. Rahardja (I2R)]**

Intra coding in the current TMuC achieves high compression efficiency, in part due to the intra prediction process that exploits spatial directional correlation. However, intra prediction of chroma components in YUV 4:2:0 video uses a limited set of possible predictions available for coding of luma components. Also, the coding of chroma components proceeds somewhat independently of luma components, and ignores any possible correlation between them. This contribution proposed a way of using reconstructed luma pixels to help with intra prediction of chroma pixels. Specifically, it uses the regions with similar luma texture characteristics to identify a location for prediction of chroma components. By making use of the reconstructed co-located luma block to perform template matching in the luma plane, co-located chroma blocks of the matched luma blocks are identified for us as predictors. Simulations results reportedly indicate that, on average, the proposed approach is able to obtain 2.3% chroma bit-rate reduction and 0.5% luma bit-rate reduction relative to the anchor for all intra coding.

An approximate 2x encoding time and 3x decoding time impact was reported for intra.

It was remarked that something like this that links together luma and chroma operations would need to provide a very good gain to be a desirable feature.

The complexity seemed rather high, but further study was encouraged.

**JCTVC-C206 Chroma intra prediction by scaled luma samples using integer operations [J. Chen, V. Seregin (Samsung)]**

This contribution proposed an integerization of the algorithm presented in JCTVC-B021 in which chroma samples are predicted from colocated reconstructed luma samples by a linear model relationship. Only addition and multiplication operations are involved to calculate the model parameter instead of using divisions as in the proposed approach. Experiments reportedly show that the average BD-rate reduction of Y, Cb, Cr components are 1.3%, 6.8% and 5.6% for intra coding conditions and 0.7%, 6.7% and 4.6% for random access conditions. The proponent asserted that the complexity of the proposed method is similar or even smaller than that of the method used in AVC.

The values of the parameters of the linear prediction model are derived at the decoder side from neighbouring reconstructed samples.

Reportedly the late document JCTVC-C314 contained a cross-verification.

Further study was encouraged.

**JCTVC-C314 Verification results of Samsung's proposal JCTVC-C206 [J. Kim , J. Park , B. Jeon] (late reg.)**

The contents of this late document were verbally reported during the presentation of JCTVC-C206. The document was not reviewed in detail. The PSNR and bit-rate results reported in this document were reported to be the same as the results reported in the document JCTVC-C206.



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**JCTVC-C111 Integration of plane mode in unified intra prediction [G. Li (Santa Clara Univ.), L. Liu, N. Ling (Santa Clara Univ.), J. Zheng, P. Zhang (Hisilicon)]**

The current default intra prediction method in the TMuC, Unified Intra Prediction, reportedly has up to 33 directional modes and 1 non-directional mode, which is the intra DC mode. This contribution proposed adding a plane mode and using an "multiple predictor set" intra mode prediction. Experimental results reportedly showed that coding efficiency can be improved with the proposed method.

Partial results for intra HE and LC configurations were provided. An average gain of about 0.6% was reported.

There seems to be several elements discussed together in this contribution.

The encoder search complexity is increased.

It was noted that the encoder search is limited by using fast search in the current TMuC, and better compression can be obtained just by making a more effective search.

Further study was encouraged.

**JCTVC-C189 Evaluation of intra prediction based on repetitive pixel replenishment [S. Mochizuki, K. Iwata (Renesas)]**

This contribution proposed a method of intra prediction based on repetitive pixel replenishment (Intra RPR).

The proposal uses a displacement vector with area extrapolation for intra coding.

Preliminary partial simulation results reportedly showed that this proposed technique has an average of 0.8%, 0.2%, 1.3% BD-rate improvement, respectively at Y, U and V, against TMuC 0.1, with about double encoding time. Only the encoding the first 20 pictures of each sequence was tested.

The reported maximum savings per sequence was 4.8% (0.22 dB) on the Basketball drill relative to TMuC 0.1. The contributor indicated that they are working on integration into a newer TMuC version.

The design, as presented, was somewhat preliminary – some modifications were planned (making the prediction size adaptive, and harmonization with other intra coding tools).

Further study was encouraged.

**JCTVC-C207 Encoder improvement of unified intra prediction [Y. Piao, J.-H. Min, J. Chen (Samsung)]**

This contribution proposed an encoding scheme for unified directional intra prediction (UIP) which was introduced in JCTVC-B100.

This was only a non-normative proposal – only the encoder would be changed – not the decoder.

Bit rate reductions of 0.5% for HE all-intra and 0.3% for LC all-intra were reported relative to the TMuC method, with lower search complexity.

The results were not cross-verified.

Two variants were proposed.

Decision: The S1 (9-9-4-4-5) scheme was adopted as the HM encoder method, with additional further study planned, and the S2 scheme will additionally be available in the HM software as a selectable configuration.



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**JCTVC-C218 Encoding complexity reduction for intra prediction by disabling NxN partition [J. Kim, Y. Jeon, B. Jeon (LG Electronics)]**

This contribution proposed a simplification of the intra prediction process to reduce encoding complexity. In the current TMuC specification, two kinds of splitting, 2Nx2N and NxN, are allowed for intra prediction and it is signaled by intra_split_flag. In the proposed method, NxN is not allowed for each intra prediction unit (PU) except when the PU has the maximum depth. The proposed modification reportedly achieves approximately 4.5% encoding time reduction with 0.2% loss in BD bit rate under the intra HE setting of JCTVC-B300. When the rotational transform (ROT) and combined intra transform (CIP) are turned off, the proposed method reportedly achieves about 36% encoding time reduction with 0.4% loss in BD bit rate relative to the anchor.

It was noted that this proposal includes syntax modification.

It was remarked that the software includes a macro switch for a similar treatment in the inter case.

Further study was suggested – perhaps as part of block structure testing rather than intra prediction.

**JCTVC-C234 Simplified intra smoothing [Y. Zheng, M. Coban, M. Karczewicz (Qualcomm)]**

In this contribution, a simplified intra smoothing scheme was proposed to improve the current AIS scheme. In the proposed scheme, the prediction samples are filtered according to the prediction unit size and the intra prediction mode. The proposed scheme reportedly achieves 0.4% BD bit rate reduction on average for HE and LC intra configurations, relative to not using any intra smoothing. The encoding complexity was reportedly reduced by about 50% relative to the prior AIS scheme.

No syntax is used to indicate whether to filter or not.

Visual quality was not studied.

Random access and low delay configurations were not tested.

The late document JCTVC-C316 reportedly contained a cross-verification report.

Further study was encouraged.

**JCTVC-C316 Verification Results of Simplified Intra Smoothing (JCTVC-C234) [T. Yamakage (Toshiba)]**

The contents of this late document were verbally reported during the presentation of JCTVC-C234. This contribution reported verification results of JCTVC-C234 (Simplified Intra Smoothing) by Qualcomm. Not all results had not been checked, but the reported results were indicated to be similar to Qualcomm's results.

**JCTVC-C302 Improved intra smoothing for UDI and new AIS fast mode [T. Nguyen, B. Bross, D. Marpe, T. Wiegand (HHI)] (late registration, missing prior, available first day)**

In this contribution, an adaption of an intra smoothing scheme for UDI was proposed to improve the overall coding performance. Furthermore, this contribution presented modified fast mode for AIS.

For when AIS is not in use, the contribution proposed a LUT without syntax to determine when filtering is to be applied. For when AIS is active, the contribution proposed a syntax indicator using the table as part of the entropy coding, and a fast encoding search method to guide the selection.

Relative to not using filtering, the LUT-only scheme in the proposal was reported to provide about 0.3% for HE and LC all-intra.

Relative to not using filtering, the scheme using syntax in the proposal was reported to provide about 0.8% for HE and 0.9% for LC in all-intra coding.

It was suggested that visual quality effects would be desirable to assess.



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The contributor did not suggest to put this into the TM, but rather to do further study.

**JCTVC-C269 A study on the impact of intra smoothing [A. Tabatabai, C. Auyeung, T. Suzuki (Sony)]**

Please see the discussion of this contribution in section 15.2.

## *18.9 Transforms and residual coding*

### 18.9.1 Residual segmentation

**JCTVC-C068 Improved side information signaling for QVBT in TMuC [B. Lee, M. Kim (KAIST), J. Kim, H.-Y. Kim (ETRI)] (missing prior, available first day)**

In this contribution, new syntax was proposed for the quadtree based transform to reduce side information for the transform in TMuC. The available maximum and minimum transform size in the current TMuC is 64x64 and 4x4 respectively, which were implemented with the quadtree-structure manner in the current version of TMuC. The structure is reportedly well adapted to the characteristics of the input signal while the signaling for transform types may cause large amounts of side information as the depth of the quadtree increases. Moreover, the coded_block_flags (cbf) for luma and chroma components are another overhead for the quadtree transform structure. The contribution proposed a modification of the side information including split_transform_unit_flag and cbf. The encoding and decoding for split_transform_unit_flag was proposed to be skipped when the cbf for luma (Y) and chroma (UV) are all zero. A new flag with a single bit was proposed to signal the patterns of the quantized coefficient for luma and chroma components.

The work reported was preliminary and no overall gain was shown.

**JCTVC-C277 Redundancy reduction in Cbf and merge coding [B. Li, J. Xu, F. Wu, G. J. Sullivan (Microsoft), H. Li (Univ. of Sci. &Tech. China)]**

In the current TMuC, tree based coding is widely used to provide a hierarchical representation of information. In some cases, the attribute of one block can be derived from the attributes of the parent block and other "brother" blocks so that the encoder does not have to code the attribute. This document presented methods to reduce redundancy in coding Cbf and merge. Remarks recorded during the review of this contribution included the following:

- Decision: The first element in the proposal contribution was regarding saving CBF bits depending on split decisions gives 0.1-0.2% reduction. It was agreed to adopt this – it adds one more condition in parsing and seems straightforward.
- The second element of the proposal contribution was regarding PU based merging and CU based merging. Further study of this aspect was suggested, and it was suggested that we would need a more precise description relative to the upcoming TMuC text and that we may have other solutions e.g. context modeling.

### 18.9.2 Transform complexity reduction

**JCTVC-C096 Low complexity rotational transform [F. C. A. Fernandes (Samsung)]**

The Rotational Transform (ROT) is a secondary transform that improves coding efficiency and is implemented in the JCT-VC Test Model under Consideration (TMuC). This contribution proposed a lifting-factorization complexity reduction for the 8x8 ROT. The ROT is split into compound Given's rotation matrices which are then each factored into a triplet of integer lifting matrices. The lifting-matrix coefficients can reportedly be implemented in hardware with fewer elemental adders than required for a TMuC ROT hardware implementation. With BD-rate of -0.003% this technique reportedly achieves 46%



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and 21% reduction in the elemental-adder count of forward and inverse ROT implementations, respectively.

The contributor recommended that the JCT-VC evaluate this transform in a tool-evaluation experiment or a core experiment.

**JCTVC-C112 Fast integer transforms for the HEVC test model [W. Dai, M. Krishnan, P. Jesudhas, P. Topiwala (FastVDO)]**

Beyond the 4x4 and 8x8 transform sizes already found in AVC, larger transform sizes of 16x16, 32x32 and 64x64 have been included in the Test Model under Consideration (TMuC) for HEVC. However, since large transform sizes have non-trivial computational complexity, one may ask what is the cost-benefit analysis of their inclusion in the forthcoming Test Model. The larger transforms in TMuC are all reportedly based on Chen's fast DCT algorithm because of its regular butterfly structure and its extensibility to any desired transform sizes of order $N=2^m$ with m>=1. For complexity reasons, integer rather than floating-point transform computation is performed. In this document, it was reported that the complexity can be reduced with no loss of performance. Fast transforms of each candidate size were proposed that reportedly not only provide virtually identical coding performance, but offer useful gains in computational complexity. In this way, the complexity of the transforms can reportedly be kept to a minimum, even when using large transform sizes.

It was remarked that lifting techniques tend to convert parallel operations into serial ones. However, it was noted that pipelining can mitigate that.

A participant asked how to best evaluate complexity – this is more than just counting operations.

**JCTVC-C255 DCT+Hadamard low complexity large transform for Inter coding [M. Budagavi, A. Gupte (TI)]**

This contribution proposed a class of transforms for large block sizes which is a combination of DCT+Hadamard transforms for reducing computational complexity of Inter transforms. The best performing 32x32 transform in this group reportedly provides most of the coding gains of 32x32 DCT for high-efficiency configurations but with 50% reduction in number of multiplications assuming direct matrix multiplication DCT. If Chen's DCT implementation is assumed, then the number of multiplications is reportedly reduced by 24%.

**JCTVC-C209 Low-complexity 16x16 and 32x32 transforms and partial frequency transform [Y.-M. Hong, M.-S. Cheon, I.-K. Kim (Samsung)]**

This contribution proposed a new 32-point fast DCT scheme based on Loeffler's design principles. Fast integer realization of the 16-point and 32-point transform were provided based on the proposed transform. In addition, a partial frequency transform scheme was proposed to reduce the complexity of the transforms of the current TMuC further. The proposed approaches reportedly reduce the number of operations significantly with negligible performance loss compared to the current TMuC.

**JCTVC-C237 Reduced complexity 32x32 transform by coefficient zero-out [J. Sole, R. Joshi, M. Karczewicz (Qualcomm)]**

Large block size transforms (up to 64×64) are being considered for HEVC for improving coding efficiency. However, such transforms may be difficult and/or costly to implement in hardware. This proposal presented an approach to simplifying the 32×32 transform by zeroing out the high frequency coefficients. The simplification reduces the number of transform coefficients by 75% and reportedly attains performance close to the full 32×32 transform. The loss in terms of BD-rate is 0.14% for random access, high efficiency configuration and 0.12% for low-delay, high efficiency configuration.

Similar to JCTVC-C209, this contribution suggested computation of only the lower frequency coefficients of a large block size transform.



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**JCTVC-C117 Implementation analysis of transform block size [Y. Yu (Broadcom)]**

This contribution analyzed the complexity of large transform block sizes, especially for a generic hardware implementation. Based on the analysis in this contribution, the hardware cost for a 64x64 transform block was reported to be roughly eight times that of an 8x8 transform block, which is the maximum transform block size of the AVC coding standard. The hardware cost for a 32x32 transform block was reported to be roughly four times that of an 8x8 transform block. The analysis also provides a compression gain comparison between different transform block sizes. The experimental results reportedly show that 80% to 90% of the total compression gain (2-4%) from large transform block sizes can be captured by 16x16 and 32x32 transform block sizes. Given the cost and compression gain, and that HEVC is also attempting to reduce overall coding complexity, this contribution suggests limiting the maximum transform block size to either 32x32 or 16x16.

It was remarked that some of the impact depends on throughput requirements – e.g., whether to process stages of a transform serially or in parallel.

The primary focus of the contribution was on hardware implementation – software may behave differently.

It was noted that quantization is a closely related topic together with transforms.

**JCTVC-C226 Low-complexity configurable transform architecture for HEVC [M. Sadafale, M. Budagavi (TI)]**

This contribution proposed a matrix multiplication architecture for DCT/IDCT implementation that is configurable and can be re-used across various transform block sizes for HEVC. Matrix multiplication implementation reportedly has the advantage that it is friendly to parallel processing with minimal dependency and control logic. In hardware, matrix multiplication reportedly results in low-area architecture, while in software it reportedly leads to efficient implementation on SIMD processors. Another asserted advantage of matrix multiplication architecture is that it is a unifying architecture in the sense that is flexible enough to support other transforms being considered in HEVC such as directional and 1D transforms. Also matrix multiplication reportedly has better fixed-point behavior than Chen's DCT/IDCT which reportedly allows for elimination of the existing quantization matrices in TMuC. The memory requirement for storing dequantization matrices in the TMuC decoder reportedly goes down from 7.5 KB to 12 bytes. There is a similar reported memory savings in the TMuC encoder. A fixed-point version of matrix multiplication DCT/IDCT along with reduced size quantization/dequantization matrices optimization was implemented in TMuC-0.7.3. Simulation results reportedly indicate that there is no significant loss in coding efficiency (average 0.0 to -0.1%) when compared to the Chen DCT/IDCT factorization in TMuC-0.7.3.

The proponent acknowledged that integration of this scheme into the TMuC would cause a substantial increase in encoder and decoder software simulation runtimes.

## 18.9.3 Alternative types of transforms

**JCTVC-C108 Jointly optimal intra prediction and adaptive primary transform [A. Saxena, F. C. A. Fernandes (Samsung)]**

This document proposed applying either a conventional discrete cosine transform (DCT) or a derived discrete sine transform (DST) for intra prediction as a primary transform in TMuC 0.7. For each of the upto 34 modes in unified intra-prediction in TMuC 0.7, the derived transform (separable along the horizontal and vertical directions) was asserted to be theoretically optimal with performance close to KLT. The proposed primary transform is based on the intra-prediction modes with no additional signaling information, works in a single-pass and reportedly does not incur any additional computational complexity. No training was required to derive the transform. It requires the storage of one sine matrix in addition to the conventional DCT at each block size. Comparison is performed in TMuC 0.7 between the proposed adaptive DCT/DST primary transform and the conventional DCT for two cases, viz., when the secondary transform in intra prediction, i.e., rotational transform is off and on. Simulation results



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reportedly show a BD Rate improvement of 0.2% and 0.1% averaged over all the video sequences, when the rotational transform is off and on, respectively. Only 25 frames of each video sequence were initially tested. Data was later collected for longer sequences, and was verbally reported to be consistent with the smaller test results.

No syntax is used to indicate the selection of transform type.

There was a previous similar proposal from I2R (see JCTVC-C037). This proposal is basically the same idea, applied to other block sizes. The contributor indicated that applying it to all block sizes may improve the results.

Further study was encouraged.

## *18.10 IBDI and memory compression*

See also the section on TE2.

**JCTVC-C077 A framework for standardization of memory compression [T. Chujoh, T. Yamakage (Toshiba)]**

A framework for standardization of memory compression was proposed. A purpose of the contribution was to discuss how to standardize memory compression. Memory compression can reduce the bandwidth of memory access; however, most memory compression techniques depend on hardware architectures and the process of memory compression causes a degradation of coding efficiency and an increase of computational complexity for most implementations. This contribution does not propose a common memory compression algorithm, but rather proposes a framework of memory compression. Since the essence of a conformance point is the output of the decoding process, it was suggested that a bitstream format and a bit rate not be specified; rather, a specification of the distortion and a system to control the distortion would be specified in this framework. The purpose of this framework is to enable introducing arbitrary memory compression effects into the encoder and the decoder in a matching fashion.

It was discussed whether encoder/decoder mismatch should be allowed. Perhaps not, but it may be a question worth discussing.

In the discussion, the creation of a related AHG was suggested.

**JCTVC-C094 An extension of DPCM-based memory compression to 2-D structure with ADPCM [H. Aoki, K. Chono, K. Senzaki, J. Tajime, Y. Senda (NEC)]**

In this contribution, a 2-D extension of the previously-proposed 1-D DPCM-based memory compression method was presented. According to some previous reports, there are conditions where 2-D image mapping to frame memory provides better memory access bandwidth performance. In such cases, memory compression with a 2-D structure may be more straightforward and may improve coding efficiency. In the proposed 2-D extension, the top-most and left-most samples in every memory compression unit are coded in the same manner as the 1-D case, and other samples are coded with ADPCM. The 1-D DPCM-based method can be regarded as a specialized version of the proposed 2-D ADPCM-based method, where its unit height is one. For each sample coded with ADPCM, the prediction value is selected in the same manner as the DC and AC prediction of the MPEG-4 part 2 standard. Experimental results were reported to have shown that the proposed 2-D ADPCM-based memory compression method has higher coding efficiency than the previously-proposed 1-D DPCM-based memory compression method. Average coding losses were reported to be 7.9% for test cases without IBDI and 1.5% for test cases 12-bit IBDI, while those of the 1-D methods are 10.0% and 1.9%, respectively. The average increase of decoding time was reported to be 3.8%. Memory bandwidth reduction ratios were reported as 45.1% for test cases without IBDI and 44.3% for test cases with 12-bit IBDI. It was proposed for the method to be adopted in TMuC software with the previously-proposed method in JCTVC-C093, and to be further evaluated in various aspects.



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**JCTVC-C095 Performance improvement of DPCM-based memory compression by adaptive quantization [H. Aoki, K. Chono, K. Senzaki, J. Tajime, Y. Senda (NEC)]**

This contribution presented a method for improving coding efficiency of DPCM-based memory compression. In the proposed method, a nonlinear quantization matrix for each memory compression unit (MCU) was adaptively selected from multiple quantization matrices so as to fit quantizer characteristics to image characteristics of each MCU. Each index to the selected quantization matrix is embedded into the compressed data and signaled to the frame memory decompressor. The actual frame memory size and memory access bandwidth reportedly does not increase as the result of this additional signaling, since the indices can reportedly be embedded into a gap area for memory alignment. Experimental results have reportedly shown that the proposed adaptive quantization can reduce the coding loss from 10.7% to 6.9% for test cases without IBDI, and from 2.0% to 1.3% for test cases with 12-bit IBDI, respectively. When applied to the 2-D version presented in JCTVC-C094, more gains were reported to have been achieved and the coding loss can reportedly be reduced to 4.8% for test cases without IBDI and to 1.0% for test cases with 12-bit IBDI, respectively. The average increase of decoding times against anchors was reported to be 14.7% for LC cases and 12.4% for HCE cases when four matrices were used. It can reportedly be shown that the proposed adaptive quantization provides flexibility on the trade-off between coding efficiency and complexity to the DPCM-based memory compression scheme.

Anomolous results were reported for Class E coding effects of memory rounding. This should be investigated.

## *18.11 Complexity analysis*

**JCTVC-C228 A simple cache model for measuring motion compensation bandwidth [M. Budagavi (TI)]**

Motion compensation reference data accesses dominate the external memory bandwidth requirements in video decoder system. External memory access bandwidth requirements are expected to increase with HEVC since HEVC motion compensation interpolation filters are longer than those in AVC and since HEVC is expected to be used with larger resolution video such as 4Kx2K and 8Kx4K. External memory bandwidth used directly impacts power consumed and cost; in fact, power consumed due to external memory accesses in a video decoder can reportedly equal the power consumed by computational processing in video decoding. Hence techniques that reduce external memory bandwidth are desirable. Memory compression is one technique that is being studied in TE2 and Memory compression AhG for reducing external memory accesses. This contribution proposed a cache model for use in measuring external memory access bandwidth. The cache model is built on top of NEC's memory bandwidth measurement module in TMuC-0.7. The main asserted goal of this work was to have a simple cache model that captures the most relevant parameters for comparing bandwidth consumed with and without memory compression and that is fair to all block structures used in memory compression. The goal was reportedly not to develop a very sophisticated cache model. This cache model can also be used to compare memory bandwidth requirements of various interpolation filters. The cache model was reportedly developed as a part of Memory Compression AhG.

It was agreed to include this in the reference software.

The AHG on complexity analysis should perform an example study e.g. for multi-pass and single-pass loop filter optimization to assess the validity of the measurement.

**JCTVC-C072 TE2: Improved memory bandwidth measurement model for reference frame compression [J. Chen, X. Shen, L. Yu (Zhejiang Univ.)]**

A memory-bandwidth measurement model for reference frame compression algorithm was proposed. This proposal analyses reference frame decompression processes and divides them into parsing process and decoding process, in which three new concepts, parsing unit, decoded area and decoding area, are defined. Based on this, a memory access area conduction method had been designed to determine the memory access area.



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It was asserted that the proposed model can still be efficient when memory compression unit is not equal to decompressible unit. It expands the scope of application and can measure memory bandwidth for more general reference frame compression algorithms.

The contribution was noted.

It was remarked that this is based on software that was provided to TE2 participants.

It was suggested to work with TE coordinators to determine its appropriateness for upcoming experiments.

# 19 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)<br>• Coordinate overall JCT-VC interim efforts<br>• Report on project status to JCT-VC reflector<br>• Provide report to next meeting on project coordination status | G. J. Sullivan, J.-R. Ohm (co-chairs) | N |
| HEVC Draft and Test Model editing<br>(jct-vc@lists.rwth-aachen.de)<br>• Produce and finalize JCTVC-C402 HEVC Test Model 1 (HM 1) Encoder Description<br>• Produce and finalize JCTVC-C403 HEVC text specification Working Draft 1<br>• Gather and address comments for refinement of these documents<br>• 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 |



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| | | |
|---|---|---|
| Software development and HM software technical evaluation<br><br>(jct-vc@lists.rwth-aachen.de)<br><br>• Coordinate development of the HM software and its distribution to JCTVC members<br>• Produce documentation of software usage for distribution with the software<br>• Deliver TMuC 0.9 software version and the reference configuration encodings according to JCTVC-C500 for use in common conditions experiments.<br>• Edit JCTVC-C500 to reflect configurations required to run the software in "HM mode".<br>• Deliver HM 1.0 and corresponding reference configuration encodings according to JCTVC-C500. (HM 1.0 will be a stripped version of TMuC 0.9 wherein tools not included in HM are removed from the codebase.)<br>• Coordinate with HEVC Draft and Test Model editing AhG to identify any mismatches between software and text | F. Bossen (chair),<br>D. Flynn, K. Sühring (vice chairs) | N |
| Slice support development and characterization<br><br>(jct-vc@lists.rwth-aachen.de)<br><br>• Implement basic slice support (independently-decodable sequences of largest coding units in raster-scan order) into the HM software.<br>• Identify issues relating to the draft text description of slice functionality<br>• Coordinate the integration of slice support with the software development and HM software technical evaluation ad hoc group<br>• Study technical proposals relating to slice structured coding<br>• Study the coding efficiency and loss resilience impact of slice-structured coding<br>• Identify and discuss additional issues relating to slice-structured coding | R. Sjöberg (chair),<br>Y. Chen, K. Kazui (vice chairs) | |



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| | | |
|---|---|---|
| Spatial Transforms<br>(jct-vc@lists.rwth-aachen.de)<br>• Study the transforms in the HM design, including compression performance, computational complexity, dynamic range, storage requirements, etc.<br>• Perform analysis of block transform design and architecture, including software and hardware considerations.<br>• Discuss transform-related Core Experiments, and identify potential synergies or incompatibilities related to the tools being tested in the CEs.<br>• Report the results and conclusions of these discussions and experiments to the JCT-VC. | P. Topiwala (chair),<br>M. Budagavi, R. Cohen, R. Joshi (vice chairs) | N |
| In-loop and post-processing filtering<br>(jct-vc@lists.rwth-aachen.de)<br>• 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, combination of filters<br>• Study trade-offs and characteristics of filter designs including complexity and subjective and objective performance<br>• Discuss relationships and evaluation procedures for the filtering techniques<br>• Identify possibilities for harmonization of enhanced in-loop filtering technologies<br>• Study the relationship between in-loop and post-processing filtering | T. Yamakage (chair),<br>K. Chono, Y. J. Chiu, I. S. Chong, M. Narroschke (vice chairs) | N |
| Coding block structures<br>(jct-vc@lists.rwth-aachen.de)<br>• Study techniques of HM relating to coding block structure<br>• Characterize the trade-offs involved in coding block structure issues, including complexity, redundancy and compression performance aspects<br>• Identify opportunities for harmonization and simplification of coding block structure | K. Panusopone (chair), W.-J. Han, T. K. Tan, T. Wiegand (vice chairs) | N |



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| | | |
|---|---|---|
| Reference pictures memory compression<br>(jct-vc@lists.rwth-aachen.de)<br>• Study motion compensation memory access bandwidth of HM design<br>• Study coding efficiency loss caused by fixed rounding of extended bit depth values for reference picture storage.<br>• Study the visual quality impact of reference picture memory compression<br>• Study use cases for memory compression techniques<br>• Study the appropriate scope of standardization for memory compression<br>• Report on conclusions reached | K. Chono (chair),<br>T. Chujoh, C. S. Lim, A. Tabatabai, M. Zhou (vice chairs) | N |
| Entropy coding<br>(jct-vc@lists.rwth-aachen.de)<br>• Study the entropy coding complexity and compression characteristics of CABAC, LCEC, PIPE/V2V, and other entropy coding designs<br>• Characterize throughput, memory, silicon area, power requirements, etc.<br>• Study parallel context processing, syntax-element partitioning, and other parallelism approaches for entropy coding<br>• Study and develop approaches for hardware and software evaluation of entropy coding methods<br>• Identify and discuss additional issues on entropy coding | M. Budagavi (chair),<br>G. Martin-Cocher, A. Segall (vice chairs) | N |
| Entropy slices<br>(jct-vc@lists.rwth-aachen.de)<br>• Study entropy slice coding methods<br>• Evaluate the compression performance and other characterstics of entropy slices relative to conventional slices<br>• Analyze impacts of throughput, latency, and memory bandwidth for entropy slice methods for various architectures<br>• Develop and perform experiments evaluating entropy slice methods<br>• Identify and discuss additional issues relating to entropy slices | A. Segall (chair)<br>V. Sze, Y.-W. Huang (vice chairs) | N |



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| | | |
|---|---|---|
| Video test material selection<br>(jct-vc@lists.rwth-aachen.de)<br>• Identify, collect, and make available a variety of video sequence test material<br>• Study the coding performance and characteristics of test materials<br>• Identify and recommend appropriate test materials and corresponding test conditions for use in HEVC development | T. Suzuki (chair) | N |
| Complexity assessment<br>(jct-vc@lists.rwth-aachen.de)<br>• Investigate measurement criteria to assess the complexity of encoder and decoder algorithmic design elements, including computational complexity, parallelism, memory bandwidth, memory capacity, dynamic range requirements, etc.<br>• Identify and recommend tools for algorithmic complexity assessment | D. Alfonso (chair),<br>J. Ridge, X. Wen (vice chairs) | N |
| Motion compensation interpolation<br>(jct-vc@lists.rwth-aachen.de)<br>• Study the coding efficiency and complexity characteristics of proposed interpolation filtering methods<br>• Study the potential for using a unified motion compensation interpolation approach for high efficiency and low complexity configurations<br>• Draft proposed core experiments relating to motion compensation interpolation<br>• Identify and discuss additional issues relating to motion compensation filtering | K. Ugur (chair),<br>E. Alshina, P. Chen, T. Chujoh (vice chairs) | N |

# 20 Core Experiment planning and Common Conditions

## *20.1 General issues for CEs*

Because the first working draft and HEVC test model (referred to as the HM) have now been selected, 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 CE X.a, CE X.b, etc., for a CE X, 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. The general agreed common conditions for experiments were described in the output document JCTVC-C500.



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A deadline of twp 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 "third party perspective", not a company proponent perspective). 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.

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 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 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.

Non-final CE plan documents were reviewed and given tentative approval during the meeting.

The particular CEs planned at this meeting were documented in the documents numbered JCTVC-C5xx, with xx = 01, 02, etc.

The CE description for each planned CE is described in an associated output document JCTVC-B3xx for CExx, where "xx" is the CE number.

It must be understood that the JCT-VC is not obliged to accept 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).

### *20.2 Common Conditions*

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-C500.

## 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.

**JCTVC-C400 Meeting Report of 3rd JCTVC Meeting [G. J. Sullivan, J.-R. Ohm]**



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**JCTVC-C401 The process of Test Model development for the HEVC initiative [G. J. Sullivan, J.-R. Ohm]**

**JCTVC-C402 High Efficiency Video Coding (HEVC) Test Model 1 (HM 1) Encoder Description [K. McCann (primary), B. Bross, S. Sekiguchi]**

**JCTVC-C403 High Efficiency Video Coding (HEVC) text specification Working Draft 1 [T. Wiegand (primary), W.-J. Han, G. J. Sullivan, J.-R. Ohm]**

**JCTVC-C404 HEVC Software guidelines [D. Flynn, K. Sühring]**

**JCTVC-C405 Summary of HEVC Model (HM) and Working Draft 1 [T.K. Tan, G. J. Sullivan , J.-R. Ohm]**

**JCTVC-C500 Common HM test conditions and software reference configurations [F. Bossen]**

**JCTVC-C501 Core Experiment 1: Decoder-side Motion Vector Derivation [Y.-J. Chiu (primary), H. Yu, Y.-W. Huang, S. Sekiguchi]**

**JCTVC-C502 Core Experiment 2: Flexible Motion Partitioning [E. Francois (primary), X. Zheng, P. Chen]**

**JCTVC-C503 Core Experiment 3: Interpolation for MC (Luma) [T. Chujoh]**

**JCTVC-C504 Core Experiment 4: Interpolation for MC (Chroma) [E. Alshina (primary), Y.-L. Lee, P. Chen, H. Lakshman]**

**JCTVC-C505 Core Experiment 5: Low Complexity Entropy Coding Improvement [X. Wang]**

**JCTVC-C506 Core Experiment 6: Intra prediction improvements [A. Tabatabai (primary), A. Tanizawa, A. Segall, H. Yu, S. Lei, J. Xu, J. Chen, Y.-J. Jeon, G. Li, M. Mrak]**

**JCTVC-C507 Core Experiment 7: Alternative transforms [R. Cohen (primary), C. Yeo, R. Joshi]**

**JCTVC-C508 Core Experiment 8: In-Loop filtering [T. Yamakage (primary), T. Chujoh, Y. W. Huang, K. Chono, I. S. Chong, T. Yamamoto, J. Lim, B. Jeon, J. Xu, M. Narroschke]**

**JCTVC-C509 Core Experiment 9: MV coding [J. Jung, B. Bross]**

**JCTVC-C510 Core Experiment 10: Number of Intra Prediction Directions [K. Sugimoto]**

**JCTVC-C511 Core Experiment 11: Coefficient Scanning and Coding [V. Sze (primary), K. Panusopone, J. Chen, T. Nguyen, M. Coban]**

**JCTVC-C512 Core Experiment 12: Adaptive Motion Vector Resolution [W.-J. Chien]**

**JCTVC-C513 Core Experiment 13: Intra Smoothing [M. Coban (primary), B. Bross, J. Chen]**



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# 22 Future meeting plans and closing of the meeting

Future meeting plans were kept as previously planned:

- Meeting under ITU-T SG 16 auspices when it meets (starting meetings on the Wednesday of the first week and closing it on the 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 Thursday prior to such meetings and closing it on the last day of the WG 11 meeting).

The JCT-VC chairmen proposed to hold the 4th JCT-VC meeting during 20-28 January 2011 under WG11 auspices in Daegu, KR. Further JCT-VC meetings are proposed to be held during 16-23 March 2011 under ITU-T auspices in Geneva, CH, and during 14-22 July 2011 under WG 11 auspices in Torino, IT.

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 Sun Yat-Sen University, Peking University, and Guangzhou CHNAVS Digital Technology Co., Ltd.

The meeting was closed at approximately 1:30 p.m. on Friday 15 October.



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# Annex A to JCT-VC report:
# List of documents

| JCT-VC number | MPEG number | Created | First upload | Last upload | Title | Source |
|---|---|---|---|---|---|---|
| JCTVC-C001 | m18041 | 2010-09-27 22:20:52 | 2010-10-07 01:42:48 | 2010-10-07 01:42:48 | JCT-VC AHG report: JCT-VC project management | G. J. Sullivan, J.-R. Ohm (co-chairs) |
| JCTVC-C002 | m18042 | 2010-09-27 22:25:08 | 2010-10-07 04:39:50 | 2010-10-07 04:39:50 | JCT-VC AHG report: Test Model under Consideration (TMuC) editing | K. McCann (chair), M. Karczewicz, J. Ridge, S. Sekiguchi, T. Wedi, T. Wiegand (vice-chairs) |
| JCTVC-C003 | m18043 | 2010-09-27 22:27:18 | 2010-10-13 01:40:29 | 2010-10-13 01:40:29 | JCT-VC AHG report: Software development and TMuC software technical evaluation | F. Bossen (chair), P. Chen, D. Flynn, W.-J. Han, K. Sühring, H. Schwarz, K. Ugur (vice-chairs) |
| JCTVC-C004 | m18044 | 2010-09-27 22:29:13 | 2010-10-02 10:02:13 | 2010-10-08 10:12:20 | JCT-VC AHG report: Alternative transforms | R. Cohen, R. Joshi (co-chairs) |
| JCTVC-C005 | m18045 | 2010-09-27 22:31:47 | 2010-10-01 15:02:14 | 2010-10-07 09:04:55 | JCT-VC AHG report: In-loop and post-processing filtering | T. Yamakage (chair), Y. J. Chiu, M. Karczewicz, M. Narroschke (co-chairs) |
| JCTVC-C006 | m18046 | 2010-09-27 22:34:03 | 2010-10-04 20:24:30 | 2010-10-04 20:24:30 | JCT-VC AHG report: Large block structures | K. Panusopone (chair), M. Budagavi, W.-J. Han, D. He (vice- |



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| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | chairs) |
| JCTVC-C007 | m18047 | 2010-09-27 22:35:40 | 2010-10-01 12:46:27 | 2010-10-05 12:57:57 | JCT-VC AHG report: Memory compression | K. Chono (chair), T. Chujoh, C. S. Lim (vice-chairs) |
| JCTVC-C008 | m18048 | 2010-09-27 22:40:30 | 2010-10-05 01:57:23 | 2010-10-05 01:57:23 | JCT-VC AHG report: Parallel entropy coding | M. Budagavi, A. Segall (co-chairs) |
| JCTVC-C009 | m18049 | 2010-09-27 22:47:50 | 2010-10-07 04:41:43 | 2010-10-07 04:41:43 | JCT-VC AHG report: Screen content coding | J. Xu, W. Ding (co-chairs) |
| JCTVC-C010 | m18050 | 2010-09-27 22:55:14 | 2010-10-02 23:17:02 | 2010-10-02 23:17:02 | JCT-VC AHG report: Complexity assessment | D. Alfonso (chair), J. Ridge, X. Wen (vice-chairs) |
| JCTVC-C021 | m18028 | 2010-09-25 01:53:37 | 2010-10-02 23:19:39 | 2010-10-05 13:03:21 | Evaluation result of JCTVC-B031 | K. Kazui, J. Koyama, A. Nakagawa (Fujitsu) |
| JCTVC-C022 | m18032 | 2010-09-25 12:24:14 | 2010-09-25 12:25:31 | 2010-09-25 12:25:31 | WG11 USNB contribution: Suggested practices for the HEVC project in the JCT-VC | A. G. Tescher (for USNB to WG11) |
| JCTVC-C023 | m18033 | 2010-09-25 12:27:32 | 2010-09-25 12:28:38 | 2010-09-25 12:28:38 | WG11 USNB contribution: HEVC standardization timeline | A. G. Tescher (for USNB to WG11) |
| JCTVC-C024 | m18035 | 2010-09-27 08:40:56 | 2010-10-01 10:49:44 | 2010-10-02 11:21:12 | TE1: Cross-check result of DMVD proposal JCTVC-C124 (Mitsubishi) | T. Murakami, T. Yokoyama, K. Nakamura (Hitachi) |
| JCTVC-C025 | m18036 | 2010-09-27 19:25:11 | 2010-10-01 11:21:22 | 2010-10-01 11:21:22 | CTB splitting on frame boundary for arbitrary resolution video | F. Yang, W. Li, S. Wan, Y. Chang (Xi'dian Univ.) |
| JCTVC-C026 | m18037 | 2010-10-01 17:46:23 | 2010-10-02 23:23:44 | 2010-10-02 23:23:44 | Proposal of frame parameters FLCTB and FSCTB for video content fitting | F. Yang, W. Li, S. Wan, Y. Chang (Xi'dian Univ.) |
| JCTVC-C027 | m18038 | 2010-09-27 19:31:40 | 2010-10-02 23:24:28 | 2010-10-05 17:05:48 | TE7: Verification results of Peking Univ. proposal (mode-dependent residual reordering for intra prediction residual) | J. Kim, B. Jeon (LG Electronics) |
| JCTVC-C028 | m18039 | 2010-09-27 19:34:29 | 2010-10-02 23:25:17 | 2010-10-02 23:25:17 | TE6: Verification results of Huawei and Hisilicon proposals (short distance intra prediction using the correlation between lines and pixels) | J. Kim, B. Jeon (LG Electronics) |



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|---|---|---|---|---|---|---|
| JCTVC-C029 | m18040 | 2010-09-27 19:56:17 | 2010-10-02 23:25:50 | 2010-10-02 23:25:50 | TE12: Report on 64x64 versus 32x32 maximum coding unit size for low complexity configuration | P. Pandit (Harmonic) |
| JCTVC-C030 | m18051 | 2010-09-28 03:15:03 | 2010-10-04 02:56:39 | 2010-10-05 08:56:34 | TE12: Report on AMP evaluation | E. Francois (Technicolor), L. Guillo (INRIA), A. Ichigaya (NHK), H. Yu (Huawei) |
| JCTVC-C031 | m18052 | 2010-09-28 03:22:04 | 2010-10-02 10:26:11 | 2010-10-08 13:16:23 | TE3 subtest 2: Report on simplified geometry block partitioning | E. Francois, D. Thoreau, P. Bordes (Technicolor), L. Guillo (INRIA) |
| JCTVC-C032 | m18053 | 2010-09-28 06:28:12 | 2010-10-02 23:26:35 | 2010-10-05 08:34:08 | Characteristics of Super Hi-Vision test sequences | Y. Shishikui, Y. Matsuo, A. Ichigaya, K. Iguchi, S. Sakaida (NHK) |
| JCTVC-C033 | m18054 | 2010-09-28 07:07:40 | 2010-10-02 23:28:06 | 2010-10-11 11:39:59 | TE3: Motion compensation with adaptive warped reference | S. Park, J. Park, B. Jeon (LG Electronics) |
| JCTVC-C034 | m18055 | 2010-09-28 20:36:36 | 2010-10-02 10:27:44 | 2010-10-08 03:48:17 | TE3 subtest 2: Cross-check of results from Huawei | E. Francois, P. Bordes (Technicolor) |
| JCTVC-C035 | m18056 | 2010-09-28 21:04:38 | 2010-10-02 09:16:00 | 2010-10-02 09:16:00 | TE7: Cross-verification of the 1D directional unified transform in TMuC | R. Cohen, A. Vetro, H. Sun (Mitsubishi) |
| JCTVC-C036 | m18057 | 2010-09-28 21:06:39 | 2010-10-02 09:16:35 | 2010-10-09 14:12:55 | Alternative performance measurement of MDDT and ROT in TMuC | R. Cohen, A. Vetro, H. Sun (Mitsubishi) |
| JCTVC-C037 | m18058 | 2010-09-28 21:22:52 | 2010-10-02 23:31:56 | 2010-10-07 17:54:33 | TE7: Results for mode-dependent fast separable KLT for block-based intra coding | C. Yeo, Y. H. Tan, Z. Li, S. Rahardja (I2R) |
| JCTVC-C038 | m18059 | 2010-09-28 21:23:48 | 2010-10-02 23:32:29 | 2010-10-07 17:55:18 | TE7: Cross-check results of MDDT simplification proposal from Huawei | C. Yeo, Y. H. Tan, Z. Li, S. Rahardja (I2R) |
| JCTVC-C039 | m18060 | 2010-09-28 | 2010-10-02 | 2010-10-07 | Choice of transforms in MDDT for unified intra prediction | C. Yeo, Y. H. Tan, |



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| | | 21:24:39 | 23:32:57 | 17:56:13 | | Z. Li, S. Rahardja (I2R) |
| JCTVC-C040 | m18061 | 2010-09-28 21:25:38 | 2010-10-02 23:33:57 | 2010-10-07 17:56:49 | Chroma intra prediction using reconstructed luma | C. Yeo, Y. H. Tan, Z. Li, S. Rahardja (I2R) |
| JCTVC-C041 | m18062 | 2010-09-28 21:34:51 | 2010-10-01 09:57:38 | 2010-10-05 14:01:53 | TE12: Performance of partition based illumination compensation (PBIC) | A. Fujibayashi, S. Kanumuri, F. Bossen, T. K. Tan (NTT DoCoMo) |
| JCTVC-C042 | m18063 | 2010-09-28 21:36:09 | 2010-10-03 05:22:19 | 2010-10-03 05:22:19 | TE5: Results for simplification of unified intra prediction | T. K. Tan, Frank Bossen (NTT DoCoMo) |
| JCTVC-C043 | m18064 | 2010-09-28 21:37:37 | 2010-10-02 11:02:42 | 2010-10-02 11:03:26 | TE11: Simulation results of merge/skip (3.2b and 3.2d) | Y. Suzuki, F. Bossen (NTT DoCoMo) |
| JCTVC-C044 | m18065 | 2010-09-28 21:39:08 | 2010-10-03 05:23:08 | 2010-10-03 05:23:08 | TE12: Results for experiments on max CU size, RDOQ and AIS | F. Bossen, T. K. Tan (NTT DoCoMo) |
| JCTVC-C045 | m18066 | 2010-09-28 21:42:07 | 2010-10-02 23:34:53 | 2010-10-08 05:32:50 | TE6.a: Cross verification for line based intra prediction | T. K. Tan, Junya Takiue (NTT DoCoMo) |
| JCTVC-C046 | m18067 | 2010-09-28 21:44:15 | 2010-10-02 23:35:46 | 2010-10-02 23:35:46 | TE5: Summary report on simplification of unified intra prediction | T. K. Tan (NTT DoCoMo), M. Budagavi (TI), J. Lainema (Nokia) |
| JCTVC-C047 | m18068 | 2010-09-28 21:49:34 | 2010-10-02 23:36:17 | 2010-10-02 23:36:17 | TE12.4: Transform skip flag test (off vs. on) by Fraunhofer HHI | B. Bross (Fraunhofer HHI) |
| JCTVC-C048 | m18069 | 2010-09-28 21:51:55 | 2010-10-02 23:36:50 | 2010-10-02 23:36:50 | TE12.6: PIPE and LCEC tested against CABAC by Fraunhofer HHI | B. Bross (Fraunhofer HHI) |
| JCTVC-C049 | m18070 | 2010-09-28 21:53:13 | 2010-10-02 23:37:18 | 2010-10-02 23:37:18 | TE12.4: Transform coding HHI tested against Samsung proposal by Fraunhofer HHI | B. Bross (Fraunhofer HHI) |
| JCTVC-C050 | m18071 | 2010-09-28 21:54:35 | 2010-10-02 23:37:53 | 2010-10-02 23:37:53 | TE12.2: Interpolation filter SIFO and DIF tested against MOMS by Fraunhofer HHI | B. Bross (Fraunhofer HHI) |
| JCTVC-C051 | m18072 | 2010-09-28 21:55:37 | 2010-10-02 23:38:24 | 2010-10-02 23:38:24 | TE12.6: PIPE tested against LCEC by Fraunhofer HHI | B. Bross (Fraunhofer HHI) |



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| JCTVC-C052 | m18073 | 2010-09-28 21:57:07 | 2010-10-02 23:38:53 | 2010-10-02 23:38:53 | TE12.1: Block merging (MRG) test (off vs. on) by Fraunhofer HHI | B. Bross (Fraunhofer HHI) |
| JCTVC-C053 | m18074 | 2010-09-28 21:58:26 | 2010-10-02 23:39:24 | 2010-10-02 23:39:24 | TE12.3: Adaptive intra smoothing (AIS) test (slow vs. fast) by Fraunhofer HHI | B. Bross (Fraunhofer HHI) |
| JCTVC-C054 | m18075 | 2010-09-28 21:59:57 | 2010-10-02 23:39:52 | 2010-10-02 23:39:52 | TE12.3: Adaptive intra smoothing (AIS) test (off vs. on) by Fraunhofer HHI | B. Bross (Fraunhofer HHI) |
| JCTVC-C055 | m18078 | 2010-09-29 23:45:27 | 2010-10-02 23:40:24 | 2010-10-15 10:09:49 | Performance report of TMuC for Super Hi-Vision | K. Iguchi, A. Ichigaya, Y. Shishikui(NHK), S. Sekiguchi, A. Minezawa (Mitsubishi Electric) |
| JCTVC-C056 | m18079 | 2010-09-29 23:57:16 | 2010-10-02 00:41:39 | 2010-10-02 00:41:39 | TE12: Evaluation of transform unit (TU) size | M. Zhou, V. Sze (TI) |
| JCTVC-C057 | m18080 | 2010-09-29 23:58:56 | 2010-10-02 00:42:29 | 2010-10-02 00:42:29 | TE12: Evaluation of IBDI and TPE (transform precision extension) | M. Zhou (TI) |
| JCTVC-C058 | m18081 | 2010-09-30 00:01:06 | 2010-10-02 02:50:32 | 2010-10-05 11:51:49 | TE12: Evaluation of entropy coders: PIPE tested against CABAC | V. Sze, M. Budagavi (TI) |
| JCTVC-C059 | m18082 | 2010-09-30 00:03:32 | 2010-10-02 02:51:15 | 2010-10-08 06:34:31 | TE12: Evaluation of transform coefficient coding (HHI_TRANSFORM_CODING) with tool breakdown | V. Sze, M. Budagavi, M. Zhou (TI) |
| JCTVC-C060 | m18083 | 2010-09-30 00:04:53 | 2010-10-02 00:43:29 | 2010-10-04 13:04:42 | TE2: TI reference frame compression proposal | M. Zhou, M. Budagavi (TI) |
| JCTVC-C061 | m18084 | 2010-09-30 00:05:42 | 2010-10-02 08:38:43 | 2010-10-09 02:06:09 | TE5: TI evaluation of unified intra prediction simplifications | M. Budagavi (TI) |
| JCTVC-C062 | m18085 | 2010-09-30 00:06:21 | 2010-10-02 08:39:45 | 2010-10-09 09:40:07 | TE8: TI parallel context processing (PCP) proposal | M. Budagavi (TI) |
| JCTVC-C063 | m18086 | 2010-09-30 00:07:15 | 2010-10-02 02:52:02 | 2010-10-10 08:13:02 | TE8: Evaluation of RIM parallel context processing (PCP) proposal | V. Sze, M. Budagavi (TI) |
| JCTVC-C064 | m18087 | 2010-09-30 00:08:17 | 2010-10-02 02:52:40 | 2010-10-10 08:19:41 | TE8: Evaluation of RIM-V2V entropy coding | V. Sze, M. Budagavi (TI) |
| JCTVC-C065 | m18088 | 2010-09-30 00:10:37 | 2010-10-02 00:44:08 | 2010-10-04 13:05:34 | Testing results on the simplified TMuC configurations | M. Zhou (TI) |



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| JCTVC-C066 | m18089 | 2010-09-30 00:11:31 | 2010-10-02 00:44:35 | 2010-10-02 00:44:35 | Cross verification of Mitsubishi 0.7.4 configuration | M. Zhou (TI) |
| JCTVC-C067 | m18090 | 2010-09-30 00:24:33 | 2010-10-03 05:26:12 | 2010-10-06 19:29:37 | TE9: Report on large block structure testing | J. Kim, M. Kim (KAIST), J. Kim, H.-Y. Kim (ETRI), K. Sato (SONY), X. Shen, L. Yu (Zhejiang Univ.), K. Choi, E. S. Jang (Hanyang Univ.), B. Bross (HHI), W.-J. Han (Samsung), J.-K. Jo, S.-N. Park, D. G. Sim, S.-J. Oh (Kwangwoon Univ.) |
| JCTVC-C068 | m18091 | 2010-09-30 00:28:31 | 2010-10-05 15:45:15 | 2010-10-11 18:16:12 | Improved side information signaling for QVBT in TMuC | B. Lee, M. Kim (KAIST), J. Kim, H.-Y. Kim (ETRI) |
| JCTVC-C069 | m18092 | 2010-09-30 00:36:29 | 2010-10-03 05:27:20 | 2010-10-03 05:27:20 | TE3: Test results of second order prediction [Withdrawn] | S. Li, L. Yu (Zhejiang Univ.) |
| JCTVC-C070 | m18093 | 2010-09-30 00:38:45 | 2010-10-02 23:41:19 | 2010-10-02 23:41:19 | TE7: Cross-check for I2R proposal on mode-dependent fast separable KLT for block-based intra coding | X. Zhu, L. Yu (Zhejiang Univ.) |
| JCTVC-C071 | m18094 | 2010-09-30 00:40:05 | 2010-10-02 23:41:48 | 2010-10-09 13:12:41 | TE10 subset 2: Complexity analysis on Wiener-based in-loop filters | L. Wang, L. Yu (Zhejiang Univ.) |
| JCTVC-C072 | m18095 | 2010-09-30 00:41:35 | 2010-10-02 23:42:24 | 2010-10-07 09:09:05 | TE2: Improved memory bandwidth measurement model for reference frame compression | J. Chen, X. Shen, L. Yu (Zhejiang Univ.) |
| JCTVC-C073 | m18096 | 2010-09-30 00:47:07 | 2010-10-02 23:42:50 | 2010-10-08 12:17:08 | TE2: Reference frame compression using image coder | C. S. Lim, V. Wahadaniah, S. Naing, H. W. Sun (Panasonic) |
| JCTVC-C074 | m18097 | 2010-09-30 00:48:41 | 2011-01-15 00:06:27 | 2011-01-15 00:06:27 | TE2: Cross-check of memory compression results from NEC (JCTVC-B057/JCTVC-C093) [Initially uploaded to the prior document archive site] | C. S. Lim, V. Wahadaniah, S. Naing, H. W. Sun (Panasonic) |



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| JCTVC-C075 | m18098 | 2010-09-30 00:51:25 | 2010-10-02 05:46:14 | 2010-10-09 11:53:28 | TE2: Adaptive scaling for bit depth compression on IBDI | T. Chujoh, T. Yamakage (Toshiba) |
| JCTVC-C076 | m18099 | 2010-09-30 00:53:40 | 2010-10-01 16:18:45 | 2010-10-07 04:25:02 | TE2: Summary of TE2 on IBDI and memory compression | T. Chujoh (TE coordinator) |
| JCTVC-C077 | m18100 | 2010-09-30 00:54:32 | 2010-10-02 11:00:51 | 2010-10-09 11:56:15 | A framework for standardization of memory compression | T. Chujoh, T. Yamakage (Toshiba) |
| JCTVC-C078 | m18101 | 2010-09-30 00:57:13 | 2010-10-02 05:48:00 | 2010-10-09 08:12:21 | TE3 subtest 4: High accuracy interpolation filter (HAIF) | T. Chujoh, K. Kanou, T. Yamakage (Toshiba) |
| JCTVC-C079 | m18102 | 2010-09-30 00:58:22 | 2010-10-02 01:23:19 | 2010-10-09 01:03:09 | TE6 subset a: Bidirectional intra prediction | T. Shiodera, A. Tanizawa, T. Chujoh, T. Yamakage (Toshiba) |
| JCTVC-C080 | m18103 | 2010-09-30 00:59:49 | 2010-10-02 01:35:44 | 2010-10-08 11:57:55 | TE7: One-dimensional directional unified transform | A. Tanizawa, J. Yamaguchi, T. Shiodera, T. Chujoh, T. Yamakage (Toshiba) |
| JCTVC-C081 | m18104 | 2010-09-30 01:01:17 | 2010-10-02 01:30:04 | 2010-10-02 01:30:04 | TE7: Cross-verification of mode dependent residual reordering (Peking Univ.) | A. Tanizawa, J. Yamaguchi (Toshiba) |
| JCTVC-C082 | m18105 | 2010-09-30 01:03:24 | 2010-10-01 15:03:34 | 2010-10-10 05:51:17 | TE10 subtest 2: Reduction of number of encoding passes for quadtree adaptive loop filter (QALF) | T. Yamakage, T. Chujoh, T. Watanabe (Toshiba) |
| JCTVC-C083 | m18106 | 2010-09-30 01:04:51 | 2010-10-01 15:04:28 | 2010-10-11 02:34:48 | TE10: Summary of TE10 on in-loop filtering | K. Chono, T. Yamakage (TE coordinators) |
| JCTVC-C084 | m18107 | 2010-09-30 01:06:25 | 2010-10-01 15:05:17 | 2010-10-12 06:38:08 | Coding efficiency report of modification by TMuC draft005 | T. Yamakage, T. Chujoh, T. Watanabe |



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| | | | | | | (Toshiba) |
| JCTVC-C085 | m18108 | 2010-09-30 01:07:49 | 2010-10-01 15:06:09 | 2010-10-09 11:33:40 | Comparison of loop & post filtering for in-loop and post-processing filtering AHG | T. Yamakage, T. Chujoh, T. Watanabe (Toshiba) |
| JCTVC-C086 | m18109 | 2010-09-30 01:08:53 | 2010-10-01 15:44:36 | 2010-10-01 15:44:36 | Experimental results of ALF on low complexity | T. Chujoh, T. Yamakage (Toshiba) |
| JCTVC-C087 | m18110 | 2010-09-30 01:09:49 | 2010-10-01 15:46:14 | 2010-10-01 15:46:14 | TE12.2: Experimental results of interpolation filter | T. Chujoh, K. Kanou, T. Yamakage (Toshiba) |
| JCTVC-C088 | m18111 | 2010-09-30 01:10:37 | 2010-10-01 15:47:41 | 2010-10-01 15:47:41 | TE12.7: Experimental results of IBDI | T. Chujoh, T. Yamakage (Toshiba) |
| JCTVC-C089 | m18112 | 2010-09-30 01:20:39 | 2010-10-02 23:43:44 | 2010-10-08 11:32:37 | TE7: Results for mode-dependent residual reordering for intra prediction residual | X. Zhao, L. Zhang, S. Ma, W. Gao (Peking Univ.) |
| JCTVC-C090 | m18113 | 2010-09-30 01:30:24 | 2010-10-02 23:44:30 | 2010-10-02 23:44:30 | TE7: Cross-verification results of mode-dependent fast separable KLT for block-based intra coding from I2R | X. Zhao, L. Zhang, S. Ma, W. Gao (Peking Univ.) |
| JCTVC-C091 | m18114 | 2010-09-30 01:34:44 | 2010-10-01 21:46:06 | 2010-10-06 21:58:49 | TE10: Conditional joint deblocking-debanding filter | K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda (NEC) |
| JCTVC-C092 | m18115 | 2010-09-30 01:36:05 | 2010-10-01 15:49:32 | 2010-10-04 15:56:10 | TE12: Report on combined intra prediction evaluation | K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda (NEC) |
| JCTVC-C093 | m18116 | 2010-09-30 01:37:18 | 2010-10-01 20:05:59 | 2010-10-06 15:55:14 | TE2: 1-D DPCM-based memory compression | H. Aoki, K. Chono, K. Senzaki, J. Tajime, Y. Senda (NEC) |



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| JCTVC-C094 | m18117 | 2010-09-30 01:38:23 | 2010-10-01 20:06:55 | 2010-10-06 18:05:00 | An extension of DPCM-based memory compression to 2-D structure with ADPCM | H. Aoki, K. Chono, K. Senzaki, J. Tajime, Y. Senda (NEC) |
| JCTVC-C095 | m18118 | 2010-09-30 01:39:11 | 2010-10-01 20:07:41 | 2010-10-12 04:12:35 | Performance improvement of DPCM-based memory compression by adaptive quantization | H. Aoki, K. Chono, K. Senzaki, J. Tajime, Y. Senda (NEC) |
| JCTVC-C096 | m18119 | 2010-09-30 01:47:25 | 2010-10-02 23:45:04 | 2010-10-07 11:26:21 | Low complexity rotational transform | F. C. A. Fernandes (Samsung) |
| JCTVC-C097 | m18120 | 2010-09-30 01:52:51 | 2010-10-02 23:45:31 | 2010-10-08 08:22:26 | TE1ï¼šHuawei report on DMVD improvements in TMuC | M. Yang, S. Lin, D. Wang, J. Zhou, H. Yu (Huawei) |
| JCTVC-C098 | m18121 | 2010-09-30 01:54:56 | 2010-10-02 23:45:57 | 2010-10-07 07:58:52 | TE1: Cross-checking of DMVD results from Mitsubishi and Intel | S. Lin, D. Wang, M. Yang, H. Yu (Huawei) |
| JCTVC-C099 | m18122 | 2010-09-30 01:58:27 | 2010-10-02 23:46:25 | 2010-10-09 08:15:47 | TE3.2: Huawei & HiSilicon report on flexible motion partitioning coding | X. Zheng (HiSilicon), H. Yu (Huawei) |
| JCTVC-C100 | m18123 | 2010-09-30 02:02:22 | 2010-10-02 23:46:56 | 2010-10-02 23:46:56 | TE5: Huawei & HiSilicon report on verification test results | L. Liu (HiSilicon), J. Zhou, H. Yu (Huawei) |
| JCTVC-C101 | m18124 | 2010-09-30 02:04:44 | 2010-10-03 00:00:52 | 2010-10-03 00:00:52 | TE6.a: HiSilicon report on short distance intra prediction | C. Lai, Y. Lin (HiSilicon) |
| JCTVC-C102 | m18125 | 2010-09-30 02:07:42 | 2010-10-03 00:01:31 | 2010-10-09 11:11:12 | TE7: Symmetry-based simplification of MDDT | H. Yang, J. Zhou, H. Yu (Huawei) |
| JCTVC-C103 | m18126 | 2010-09-30 02:10:17 | 2010-10-03 00:02:02 | 2010-10-03 00:02:02 | TE7: Report of cross-checking results for Toshiba proposal | H. Yang, J. Zhou, H. Yu (Huawei) |
| JCTVC-C104 | m18127 | 2010-09-30 02:12:38 | 2010-10-03 00:02:39 | 2010-10-03 00:02:39 | TE12: Huawei & HiSilicon report on AMP evaluation | X. Zheng (HiSilicon), J. Zhou, H. Yu (Huawei) |



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| JCTVC-C105 | m18128 | 2010-09-30 02:14:42 | 2010-10-03 00:03:14 | 2010-10-03 00:03:14 | TE12: Huawei report on max transform unit size evaluation | J. Zhou, D. Wang, H. Yu (Huawei) |
| JCTVC-C106 | m18129 | 2010-09-30 02:16:10 | 2010-10-03 00:03:43 | 2010-10-09 11:06:00 | Symmetry-based scan order sharing scheme for MDDT | H. Yang, J. Zhou, H. Yu (Huawei) |
| JCTVC-C107 | m18130 | 2010-09-30 02:21:55 | | | Fast CABAC [Withdrawn] | H. J. Kim (Korea Univ.) |
| JCTVC-C108 | m18131 | 2010-09-30 02:26:17 | 2010-10-03 00:05:08 | 2010-10-12 07:00:26 | Jointly optimal intra prediction and adaptive primary transform | A. Saxena, F. C. A. Fernandes (Samsung) |
| JCTVC-C109 | m18132 | 2010-09-30 02:28:49 | 2010-10-03 01:34:36 | 2010-10-15 05:38:13 | TE12.1: Results for PU-based merging by Fraunhofer HHI | B. Bross (Fraunhofer HHI) |
| JCTVC-C110 | m18133 | 2010-09-30 02:30:17 | 2010-10-03 03:03:37 | 2010-10-03 03:03:37 | TE12.4: Transform unit quadtree tested against 2-level by Fraunhofer HHI | B. Bross (Fraunhofer HHI) |
| JCTVC-C111 | m18134 | 2010-09-30 02:32:25 | 2010-10-03 03:04:57 | 2010-10-08 08:26:33 | Integration of plane mode in unified intra prediction | G. Li (Santa Clara Univ.), L. Liu, N. Ling (Santa Clara Univ.), J. Zheng, P. Zhang (Hisilicon) |
| JCTVC-C112 | m18135 | 2010-09-30 02:34:15 | 2010-10-03 03:10:10 | 2010-10-11 08:03:54 | Fast integer transforms for the HEVC test model | W. Dai, M. Krishnan, P. Jesudhas, P. Topiwala (FastVDO) |
| JCTVC-C113 | m18136 | 2010-09-30 02:38:17 | 2010-10-01 23:49:10 | 2010-10-05 04:56:56 | Adaptive loop filter with low encoder complexity | I.S. Chong, W. Chien, M. Karczewicz (Qualcomm) |
| JCTVC-C114 | m18137 | 2010-09-30 02:41:44 | 2010-10-07 10:37:25 | 2010-10-07 10:37:25 | Zigzag scan for CABAC/PIPE | J. Lou, K. Panusopone, L. Wang (Motorola) |
| JCTVC-C115 | m18138 | 2010-09-30 02:54:46 | 2010-10-03 05:29:32 | 2010-10-08 17:43:16 | TE1: Summary report of TE1 activity | Y.-J. Chiu (Intel), Y.-W. Huang (MediaTek), M. Wien (RWTH Aachen Univ.), H. |



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| | | | | | | Yu (Huawei) |
| JCTVC-C116 | m18139 | 2010-09-30 02:56:51 | 2010-10-03 03:11:33 | 2010-10-05 10:55:26 | TE11: Cross verification of Sony proposal on motion vector coding | Y.-J. Jeon, B.-M. Jeon (LG Electronics) |
| JCTVC-C117 | m18140 | 2010-09-30 03:23:03 | 2010-10-03 03:14:16 | 2010-10-03 03:14:16 | Implementation analysis of transform block size | Y. Yu (Broadcom) |
| JCTVC-C118 | m18141 | 2010-09-30 03:27:12 | 2010-10-03 03:15:16 | 2010-10-04 11:16:43 | TE12.1 cross-check report on block merging (MRG) on/off | K. Sugimoto, A. Minezawa, S. Sekiguchi (Mitsubishi Electric) |
| JCTVC-C119 | m18142 | 2010-09-30 03:27:57 | 2010-10-03 03:18:57 | 2010-10-03 03:18:57 | TE12.2 report on MV prediction AMVP/IMVP | K. Sugimoto, A. Minezawa, S. Sekiguchi (Mitsubishi Electric) |
| JCTVC-C120 | m18143 | 2010-09-30 03:28:41 | 2010-10-03 03:20:04 | 2010-10-04 11:25:35 | TE12.3 cross-check report on AIS on/off | K. Sugimoto, A. Minezawa, S. Sekiguchi (Mitsubishi Electric) |
| JCTVC-C121 | m18144 | 2010-09-30 03:30:08 | 2010-10-03 03:21:14 | 2010-10-14 01:34:45 | Suggested approach toward HEVC test model creation | S. Sekiguchi, K. Sugimoto (Mitsubishi Electric) |
| JCTVC-C122 | m18145 | 2010-09-30 03:31:08 | 2010-10-03 03:23:20 | 2010-10-06 18:27:41 | A suggested starting point for HEVC test model | K. Sugimoto, S. Sekiguchi (Mitsubishi Electric) |
| JCTVC-C123 | m18146 | 2010-09-30 03:32:06 | 2010-10-03 03:38:02 | 2010-10-03 03:38:02 | On selecting coding tools for HEVC test model | K. Sugimoto, A. Minezawa, S. Sekiguchi (Mitsubishi Electric) |
| JCTVC-C124 | m18147 | 2010-09-30 03:33:11 | 2010-10-03 03:39:49 | 2010-10-15 02:10:32 | TE1: Implicit direct vector derivation | Y. Itani, S. Sekiguchi |



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| | | | | | | (Mitsubishi Electric) |
| JCTVC-C125 | m18148 | 2010-09-30 03:34:14 | 2010-10-03 03:40:52 | 2010-10-03 03:40:52 | TE1: Spatio-temporal direct mode | S. Sekiguchi, Y. Itani (Mitsubishi Electric) |
| JCTVC-C126 | m18149 | 2010-09-30 03:37:21 | 2010-10-03 05:30:25 | 2010-10-06 07:34:38 | Chroma interpolation filtering using high precision filter | D. Y. Kim, J. P. Kim, Y. L. Lee (Sejong University), J. Lim, J. Song (SKT) |
| JCTVC-C127 | m18151 | 2010-09-30 05:39:59 | 2010-10-03 05:32:53 | 2010-10-08 10:11:44 | TE1: Report of self derivation of motion estimation improvement in TMuC | Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel) |
| JCTVC-C128 | m18152 | 2010-09-30 05:41:20 | 2010-10-03 05:33:38 | 2010-10-03 05:33:38 | TE1: Cross-checking of DMVD result from Huawei | Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel) |
| JCTVC-C129 | m18153 | 2010-09-30 05:42:33 | 2010-10-03 05:34:20 | 2010-10-08 10:13:51 | TE12: Cross verification for adaptive loop filter (ALF) (on vs. off) | Y.-J. Chiu, L. Xu, W. Zhang, H. Jiang (Intel) |
| JCTVC-C130 | m18154 | 2010-09-30 08:09:06 | 2010-10-02 16:56:13 | 2010-10-08 06:23:27 | TE10 subtest 1: Results of intra deblocking filter testing by SKKU/SKT | J. Yang, K. Won, B. Jeon (SKKU), J. Lim, J. Song (SKT) |
| JCTVC-C131 | m18155 | 2010-09-30 08:11:10 | 2010-10-02 11:49:32 | 2010-10-02 11:54:33 | TE10 subtest 1: Cross-verification result of Microsoft deblocking filter proposal by SKKU/SKT | J. Yang, K. Won, B. Jeon (SKKU), J. Lim, J. Song (SKT) |
| JCTVC-C132 | m18156 | 2010-09-30 08:12:22 | 2010-10-02 11:51:54 | 2010-10-02 11:51:54 | TE11: Cross-verification result of Orange Labs motion vector competition proposal (3.1a) by SKKU | J. Yang, K. Won, B. Jeon (SKKU) |
| JCTVC-C133 | m18157 | 2010-09-30 08:13:24 | 2010-10-02 14:50:11 | 2010-10-02 14:50:11 | Motion vector competition method with reduced candidate sets [Withdrawn] | K. Won, J. Yang, B. Jeon (SKKU), J. Lim, J. Song (SKT) |
| JCTVC-C134 | m18158 | 2010-09-30 08:20:46 | 2010-10-03 00:56:47 | 2010-10-09 11:45:55 | Comments on V2V coding for TM/TMuC | D. He, G. Korodi, P. Imthurn, J. |



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| | | | | | | Jamias, D. O'Loughlin, G. Martin-Cocher (RIM) |
| JCTVC-C135 | m18159 | 2010-09-30 08:26:07 | 2010-10-02 00:16:34 | 2010-10-11 07:58:53 | Flexible scaling of quantization parameter | D. Hoang (Zenverge) |
| JCTVC-C136 | m18160 | 2010-09-30 08:35:21 | 2010-10-01 17:42:26 | 2010-10-07 10:02:08 | TE12.4: Mode dependent direnctional transform (MDDT) test (off vs. on) by HKUST | X. Zhang (HKUST) |
| JCTVC-C137 | m18161 | 2010-09-30 08:55:58 | 2010-10-01 17:59:25 | 2010-10-01 17:59:25 | Decoder-side block boundary decision (DBBD) with OBMC | S. Fukushima (JVC) |
| JCTVC-C138 | m18162 | 2010-09-30 09:03:54 | 2010-10-01 18:08:35 | 2010-10-12 03:40:33 | TE1.a: Implementation report of refinement motion compensation using DMVD on TMuC | M. Ueda (JVC) |
| JCTVC-C139 | m18163 | 2010-09-30 09:17:39 | 2010-10-03 03:42:06 | 2010-10-10 17:35:36 | TE6.a: Huawei & HiSilicon report on cross verification of MSRA's LIC | C. Lai, Y. Lin (HiSilicon), J. Zhou (Huawei) |
| JCTVC-C140 | m18164 | 2010-09-30 14:06:56 | 2010-10-03 03:43:34 | 2010-10-07 04:03:00 | TE9-2: Report on performance tests for different sets of PU modes by Fraunhofer HHI | B. Bross (Fraunhofer HHI) |
| JCTVC-C141 | m18167 | 2010-09-30 16:24:37 | 2010-10-02 06:39:30 | 2010-10-02 06:39:30 | TE8: Crosscheck on TI's proposal of parallel context processing by MediaTek | Y.-L. Chang, Y.-W. Huang, S. Lei (MediaTek) |
| JCTVC-C142 | m18168 | 2010-09-30 16:29:48 | 2010-10-02 06:41:47 | 2010-10-05 08:56:03 | TE10 subtest 1: Improved deblocking filter | J. An, K. Zhang, Y. Gao, X. Guo, C.-M. Fu, Y.-W. Huang, S. Lei (MediaTek) |
| JCTVC-C143 | m18169 | 2010-09-30 16:31:16 | 2010-10-02 06:43:40 | 2010-10-05 17:31:12 | TE10 subtest 2: Coding unit synchronous picture quadtree-based adaptive loop filter (QALF) | C.-Y. Tsai, C.-M. Fu, C.-Y. Chen, Y.-W. Huang, S. Lei (MediaTek) |
| JCTVC-C144 | m18170 | 2010-09-30 16:32:20 | 2010-10-02 06:44:45 | 2010-10-02 06:44:45 | TE10 subtest 2: Crosscheck on TOSHIBA's proposal of adaptive loop filter by MediaTek | C.-M. Fu, Y.-W. Huang, S. Lei (MediaTek) |
| JCTVC-C145 | m18171 | 2010-09-30 16:35:47 | 2010-10-02 06:45:31 | 2010-10-02 06:45:31 | TE10 subtest 2: Crosscheck on SHARP's proposal of adaptive loop filter by MediaTek | C.-Y. Tsai, Y.-W. Huang, S. Lei (MediaTek) |



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| JCTVC-C146 | m18172 | 2010-09-30 16:38:49 | 2010-10-02 09:26:54 | 2010-10-02 09:26:54 | TE10 subtest 3: Controlled clipping | Y.-L. Chang, C.-M. Fu (MediaTek), A. Segall, Y. Su (Sharp), C.-Y. Chen, Y.-W. Huang, S. Lei (MediaTek) |
| JCTVC-C147 | m18173 | 2010-09-30 16:39:44 | 2010-10-02 06:47:02 | 2010-10-05 08:57:57 | TE10 subtest 3: Quadtree-based adaptive offset | C.-Ming Fu, C.-Y. Chen, Y.-W. Huang, S. Lei (MediaTek) |
| JCTVC-C148 | m18174 | 2010-09-30 16:40:27 | 2010-10-02 06:47:59 | 2010-10-02 06:47:59 | TE12: Crosscheck on deblocking filter in TMuC0.7 by MediaTek | Y.-L. Chang, Y.-W. Huang, S. Lei (MediaTek) |
| JCTVC-C149 | m18175 | 2010-09-30 17:44:55 | 2010-10-03 03:45:06 | 2010-10-03 03:45:06 | TE12.2: Report on asymmetric motion prediction unit (AMP) on/off | A. Ichigaya, K. Iguchi (NHK) |
| JCTVC-C150 | m18176 | 2010-09-30 17:51:58 | 2010-10-01 08:03:22 | 2010-10-07 16:25:23 | TE2: Cross-check of memory compression results from TOSHIBA (JCTVC-C075) | Y. Choe, S. Hong (Yonsei Univ.), Y-G. Kim (KGIT) |
| JCTVC-C151 | m18177 | 2010-09-30 17:56:58 | | | Reference frame denoising [Withdrawn] | P. Amon, A. Hutter, E. Wige, A. Kaup (Siemens) |
| JCTVC-C152 | m18178 | 2010-09-30 17:58:55 | 2010-10-03 03:46:04 | 2010-10-11 02:12:23 | Context-adaptive hybrid variable length coding | Y. Xu, J. Li, W. H. Chen, D. Tian (Cisco Systems) |
| JCTVC-C153 | m18179 | 2010-09-30 23:22:00 | 2010-10-01 22:09:49 | 2010-10-01 22:09:49 | TE12: Report on deblocking filter | P. Chen, M. Karczewicz (Qualcomm) |
| JCTVC-C154 | m18180 | 2010-09-30 23:34:07 | 2010-10-02 23:36:10 | 2010-10-10 16:49:20 | Fine granularity slices | R. Sjöberg, P. Wennersten (Ericsson) |
| JCTVC-C155 | m18181 | 2010-09-30 23:38:19 | 2010-10-02 23:32:09 | 2010-10-12 18:24:33 | TMuC 0.7 results with sequence dependent QPs | K. Andersson, R. Sjöberg (Ericsson) |



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| JCTVC-C156 | m18182 | 2010-09-30 23:40:22 | 2010-10-02 23:32:47 | 2010-10-09 17:33:36 | TE10: Cross verification of Mediatek's deblocking filter by Ericsson | A. Norkin, R. Sjöberg, K. Andersson (Ericsson) |
| JCTVC-C157 | m18183 | 2010-09-30 23:42:33 | 2010-10-02 23:33:13 | 2010-10-02 23:33:13 | TE6.a: Cross verification of line-based intra prediction | J. Samuelsson, R. Sjöberg, K. Andersson (Ericsson) |
| JCTVC-C158 | m18184 | 2010-09-30 23:43:54 | 2010-10-02 23:33:42 | 2010-10-02 23:33:42 | TE7: Cross verification of MDDT simplification JCTVC-B024 | K. Andersson (Ericsson) |
| JCTVC-C159 | m18185 | 2010-09-30 23:45:20 | 2010-10-02 23:34:19 | 2010-10-02 23:34:19 | TE12: Cross verification of RDOQ | K. Andersson (Ericsson) |
| JCTVC-C160 | m18186 | 2010-10-01 00:46:38 | 2010-10-01 22:27:08 | 2010-10-01 22:27:08 | TE12: Crosscheck on LCEC phase 2 | P. Chen, M. Karczewicz (Qualcomm) |
| JCTVC-C161 | m18187 | 2010-10-01 03:44:41 | 2010-10-01 17:53:36 | 2010-10-09 07:52:08 | TE10: Cross-verification result of SKKU/SKT deblocking filter | K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. Senda (NEC) |
| JCTVC-C162 | m18188 | 2010-10-01 03:50:50 | 2010-10-01 13:25:57 | 2010-10-07 11:21:48 | TE12.2: Results on MC interpolation filters | K. Kondo, T. Suzuki (Sony) |
| JCTVC-C163 | m18189 | 2010-10-01 03:52:03 | 2010-10-01 12:28:00 | 2010-10-07 11:24:05 | TE12.2: Results on MV prediction | K. Sato, T. Suzuki (Sony) |
| JCTVC-C164 | m18190 | 2010-10-01 03:53:09 | 2010-10-03 03:47:01 | 2010-10-06 18:48:25 | TE3 subset 4: Results on bi/single filter switching in FIF | K. Kondo, T. Suzuki (Sony) |
| JCTVC-C165 | m18191 | 2010-10-01 03:55:00 | 2010-10-07 17:07:35 | 2010-10-15 12:39:26 | TE3 subset 4: Cross verification on high accuracy interpolation filter | K. Kondo, T. Suzuki (Sony) |
| JCTVC-C166 | m18192 | 2010-10-01 03:55:32 | 2010-10-03 03:48:12 | 2010-10-07 03:26:25 | TE11: Study on motion vector coding (experiment 3.3.a & 3.3.c) | K. Sato (Sony) |
| JCTVC-C167 | m18193 | 2010-10-01 03:56:12 | 2010-10-03 03:49:10 | 2010-10-03 03:49:10 | Proposal on large block structure and quantization | K. Sato (Sony) |
| JCTVC-C168 | m18194 | 2010-10-01 03:57:05 | 2010-10-03 05:36:59 | 2010-10-07 11:25:57 | Comments on common test conditions | K. Kondo, K. Sato, T. Suzuki (Sony) |
| JCTVC-C169 | m18198 | 2010-10-01 | 2010-10-03 | 2010-10-12 | TE6.b: Experiment results of DCIM | E. Maani, L. |



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| | | 05:36:07 | 05:37:39 | 05:24:59 | | Dong, W. Liu (Sony) |
| JCTVC-C170 | m18199 | 2010-10-01 05:38:00 | 2010-10-03 03:50:11 | 2010-10-09 08:18:28 | TE3.2: Report on cross-verification of simplified geometry block partitioning from Technicolor | X. Zheng (HiSilicon), H. Yu (Huawei) |
| JCTVC-C171 | m18200 | 2010-10-01 05:39:20 | 2010-10-03 05:39:31 | 2010-10-05 06:35:24 | TE12.3: Experimental results of edge based prediction | A. Tabatabai, C. Auyeung (Sony) |
| JCTVC-C172 | m18201 | 2010-10-01 05:42:20 | 2010-10-03 05:40:18 | 2010-10-12 05:32:26 | TE6: Summary report of intra prediction improvements tool experiments | A. Tabatabai (Sony) |
| JCTVC-C173 | m18202 | 2010-10-01 05:45:36 | 2010-10-01 14:30:06 | 2010-10-09 11:43:19 | TE10 subtest 2: Parallel adaptive loop filter | T. Ikai, T. Yamamoto (SHARP) |
| JCTVC-C174 | m18203 | 2010-10-01 05:47:23 | 2010-10-04 10:56:35 | 2010-10-04 10:56:35 | TE12.3: Report on combined intra prediction | T. Yamamoto, A. Segall (SHARP) |
| JCTVC-C175 | m18204 | 2010-10-01 05:48:11 | 2010-10-04 10:57:06 | 2010-10-20 07:56:10 | TE6.b: Cross verification of differential coding of intra modes (DCIM) | T. Yamamoto, Y. Yasugi (SHARP) |
| JCTVC-C176 | m18205 | 2010-10-01 05:53:40 | 2010-10-01 14:30:50 | 2010-10-05 10:42:21 | Analysis and improvement of differential coding of intra modes | T. Yamamoto, Y. Yasugi (Sharp) |
| JCTVC-C177 | m18206 | 2010-10-01 06:35:49 | | | Horizontal spatial prediction for intra coding [Withdrawn] | P. Tao, D. Li, W. Wu, J. Wen (Tsinghua Univ.) |
| JCTVC-C178 | m18207 | 2010-10-01 07:11:57 | 2010-10-06 05:02:26 | 2010-10-06 05:02:26 | TE2: Cross-check of memory compression results from Panasonic (JCTVC-C074) | A. Segall (Sharp) |
| JCTVC-C179 | m18208 | 2010-10-01 07:14:25 | 2010-10-06 05:03:24 | 2010-10-06 05:03:24 | TE6: Cross-check of bi-directional intra-predition results from Toshiba | A. Segall (Sharp) |
| JCTVC-C180 | m18209 | 2010-10-01 07:18:37 | 2010-10-06 17:00:44 | 2010-10-10 02:53:54 | TE10.3: Cross check of MediaTek's proposal on quadtree-based adaptive offset | A. Segall (Sharp) |
| JCTVC-C181 | m18210 | 2010-10-01 07:21:01 | 2010-10-06 05:04:13 | 2010-10-07 08:39:06 | TE12.4: Cross-check of rotational transform (ROT) | K. Misra, A. Segall (Sharp) |
| JCTVC-C182 | m18211 | 2010-10-01 07:24:57 | 2010-10-06 10:20:39 | 2010-10-07 08:40:33 | TE12.2: Cross-check of adaptive motion vector resolution (AMVRES) technology in the TMuC software | A. Segall (Sharp) |
| JCTVC-C183 | m18212 | 2010-10-01 08:05:51 | 2010-10-02 08:01:01 | 2010-10-11 14:56:39 | Enhanced switching of interpolation filter for HEVC | T. Yoshino, S. Naito, S. Sakazawa (KDDI) |



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| JCTVC-C184 | m18215 | 2010-10-01 09:06:12 | 2010-10-03 00:03:20 | 2010-10-06 18:39:04 | TE12.6: PIPE tested against LCEC by Cisco | A. Fuldseth (Cisco) |
| JCTVC-C185 | m18216 | 2010-10-01 09:08:53 | 2010-10-03 00:03:56 | 2010-10-07 08:16:58 | Recent improvements of the low complexity entropy coder (LCEC) in TMuC | A. Fuldseth, G. BjÃ¸ntegaard (Cisco), A. Hallapuro, K. Ugur, J. Lainema (Nokia) |
| JCTVC-C186 | m18217 | 2010-10-01 09:13:37 | 2010-10-03 03:51:56 | 2010-10-03 03:51:56 | TE5: Results for simplified intra prediction tests by Nokia | J. Lainema, K. Ugur (Nokia) |
| JCTVC-C187 | m18218 | 2010-10-01 09:16:59 | 2010-10-03 03:53:00 | 2010-10-03 03:53:00 | TE6.a: Cross-check of bidirectional intra prediction (JCTVC-B042) | K. Iwata (Renesas) |
| JCTVC-C188 | m18219 | 2010-10-01 09:17:39 | 2010-10-03 03:54:10 | 2010-10-09 03:43:41 | TE12.3: Results for planar prediction tests by Nokia | J. Lainema, K. Ugur, O. Bici (Nokia) |
| JCTVC-C189 | m18220 | 2010-10-01 09:18:20 | 2010-10-03 03:58:20 | 2010-10-12 03:38:20 | Evaluation of intra prediction based on repetitive pixel replenishment | S. Mochizuki, K. Iwata (Renesas) |
| JCTVC-C190 | m18223 | 2010-10-01 11:24:27 | 2010-10-01 16:05:22 | 2010-10-02 19:16:05 | TE7: Cross-check result of Peking Univ.'s proposal (JCTVC-C089) | J. Kim, S.-C. Lim, H. Y. Kim, H. Lee, J. S. Choi (ETRI) |
| JCTVC-C191 | m18226 | 2010-10-01 11:28:00 | 2010-10-01 17:07:12 | 2010-10-04 14:16:38 | TE11: Cross-check result of merge/skip (3.2c) | S. Jeong, J. Lee, H. Y. Kim, S.-C. Lim (ETRI), K. Kim, H. Lee, G. Park (KHU) |
| JCTVC-C192 | m18228 | 2010-10-01 11:32:07 | 2010-10-01 20:55:06 | 2010-10-07 17:31:12 | TE7: Cross-verification results of Huawei proposal on simplified MDDT for intra prediction residual | Y. Choe, J. Kim (Yonsei Univ.), Y-G. Kim (KGIT) |
| JCTVC-C193 | m18230 | 2010-10-01 11:37:51 | 2010-10-02 05:48:06 | 2010-10-15 02:08:37 | Overlapped block intra prediction | K. Zhang, X. Guo, J. An, M. Guo, Y.-W. Huang, S. Lei (MediaTek) |
| JCTVC-C194 | m18231 | 2010-10-01 11:50:13 | 2010-10-03 03:59:21 | 2010-10-03 03:59:21 | TE10 subtest 2: Cross-check results of JCTVC-C082 [Toshiba] Reduction of number of encoding passes for quadtree-based adaptive loop filter (QALF) | P. Wu, S. Paschalakis, N. Sprljan (Mitsubishi |



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| JCTVC-C195 | m18232 | 2010-10-01 11:52:32 | 2010-10-03 04:01:29 | 2010-10-03 04:01:29 | An enhanced block-based adaptive loop filter in TMuC0.7.0 platform | P. Wu, S. Paschalakis, N. Sprljan (Mitsubishi Electric) |
| JCTVC-C196 | m18233 | 2010-10-01 13:32:59 | 2010-10-03 04:02:43 | 2010-10-03 04:02:43 | TE12.6: Results for LCEC_PHASE2 tests by Nokia | K. Ugur, A. Hallapuro, J. Lainema (Nokia) |
| JCTVC-C197 | m18235 | 2010-10-01 13:43:57 | 2010-10-03 04:03:34 | 2010-10-03 04:03:34 | TE12.2: Results for SIFO-6Tap with DIF tests by Nokia and Qualcomm | K. Ugur, J. Lainema (Nokia), R. Panchal, M. Karczewicz (Qualcomm) |
| JCTVC-C198 | m18236 | 2010-10-01 15:02:40 | 2010-10-02 12:24:43 | 2010-10-12 04:25:35 | TE9: Simulation results for various max. number of transform quadtree depth | J. Chen, T. Lee, W.-J. Han (Samsung) |
| JCTVC-C199 | m18237 | 2010-10-01 15:06:05 | 2010-10-02 12:28:22 | 2010-10-02 12:33:06 | TE11: Report on experiment 3.2.c: Check skip and merge together | I.-K. Kim, T. Lee, W.-J. Han (Samsung) |
| JCTVC-C200 | m18238 | 2010-10-01 15:10:38 | 2010-10-02 12:30:10 | 2010-10-06 18:44:34 | TE12.1: Experimental results of transform unit quadtree/2-level test | T. Lee, J. Chen, W.-J. Han (Samsung) |
| JCTVC-C201 | m18239 | 2010-10-01 15:16:37 | 2010-10-02 12:38:06 | 2010-10-06 19:01:07 | TE12.2: Experimental results of SIFO (DIF) / DCT-IF | E. Alshina, J. Chen, N. Shlyakhov, A. Alshin, W.-J. Han (Samsung) |
| JCTVC-C202 | m18240 | 2010-10-01 15:19:08 | 2010-10-02 13:24:16 | 2010-10-06 19:14:19 | TE12.4: Experimental results of MDDT and ROT by Samsung and Qualcomm | E. Alshina, A. Alshin, W.-J. Han (Samsung), R. Joshi, M. Coban (Qualcomm) |
| JCTVC-C203 | m18241 | 2010-10-01 15:26:15 | 2010-10-02 12:41:06 | 2010-10-02 12:41:06 | TE12.4: Experimental results of transform coefficient coding | J. Chen, V. Seregin, W.-J. Han (Samsung) |



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| JCTVC-C204 | m18242 | 2010-10-01 15:27:44 | 2010-10-03 12:30:27 | 2010-10-05 13:52:24 | Bi-directional optical flow | A. Alshin, E. Alshina (Samsung) |
| JCTVC-C205 | m18243 | 2010-10-01 15:29:50 | 2010-10-02 12:43:04 | 2010-10-07 19:03:35 | Low-complexity adaptive coefficient scanning | V. Seregin, J. Chen (Samsung) |
| JCTVC-C206 | m18244 | 2010-10-01 15:36:38 | 2010-10-02 12:44:14 | 2010-10-11 05:59:20 | Chroma intra prediction by scaled luma samples using integer operations | J. Chen, V. Seregin (Samsung) |
| JCTVC-C207 | m18245 | 2010-10-01 15:39:22 | 2010-10-02 12:47:53 | 2010-10-07 19:06:02 | Encoder improvement of unified intra prediction | Y. Piao, J.-H. Min, J. Chen (Samsung) |
| JCTVC-C208 | m18246 | 2010-10-01 15:40:37 | 2010-10-02 12:53:45 | 2010-10-08 19:35:36 | Simulation results of motion partition, block merging and motion competition schemes | I.-K. Kim, T. Lee (Samsung) |
| JCTVC-C209 | m18247 | 2010-10-01 15:43:38 | 2010-10-02 12:56:31 | 2010-10-08 02:30:43 | Low-complexity 16x16 and 32x32 transforms and partial frequency transform | Y.-M. Hong, M.-S. Cheon, I.-K. Kim (Samsung) |
| JCTVC-C210 | m18248 | 2010-10-01 15:45:42 | 2010-10-02 12:57:59 | 2010-10-05 14:06:21 | Efficient coefficient coding method for large transform in VLC mode | S. Lee, M.-S. Cheon, I.-K. Kim (Samsung) |
| JCTVC-C211 | m18249 | 2010-10-01 15:49:19 | 2010-10-02 13:00:37 | 2010-10-05 14:40:31 | Inner block oriented ALF processing for memory & bandwidth reduction | Y. Sohn, K.-H. Lee, B.-K. Lee, I.-K. Kim (Samsung) |
| JCTVC-C212 | m18250 | 2010-10-01 15:50:17 | 2010-10-02 12:25:22 | 2010-10-04 08:16:35 | Cross-verification of JCTVC-C086: Experimental results of ALF on low complexity | W.-J. Han (Samsung) |
| JCTVC-C213 | m18251 | 2010-10-01 16:11:41 | 2010-10-03 05:41:28 | 2010-10-07 06:56:55 | Additional results for combined intra prediction | M. Mrak, T.Davies, D. Flynn, A. Gabriellini (BBC) |
| JCTVC-C214 | m18254 | 2010-10-01 16:37:58 | 2010-10-01 19:03:24 | 2010-10-07 06:48:05 | TE12.5: Results for adaptive loop filter using prediction and residual | M. Narroschke (Panasonic) |
| JCTVC-C215 | m18255 | 2010-10-01 17:33:56 | 2010-10-03 04:05:02 | 2010-10-09 05:16:40 | Adaptive MV resolution with directional filters | K. Ugur, J. Lainema (Nokia) |
| JCTVC-C216 | m18256 | 2010-10-01 17:36:31 | 2010-10-01 18:48:44 | 2010-10-07 08:51:39 | TE12.3: Results for edge based prediction | V. Drugeon (Panasonic) |
| JCTVC-C217 | m18257 | 2010-10-01 | 2010-10-01 | 2010-10-08 | TE06.b: Cross verification of differential coding of intra | V. Drugeon |



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| | | 17:51:11 | 18:52:49 | 18:20:18 | modes (DCIM) | (Panasonic) |
| JCTVC-C218 | m18258 | 2010-10-01 18:15:34 | 2010-10-01 20:36:37 | 2010-10-11 11:31:48 | Encoding complexity reduction for intra prediction by disabling NxN partition | J. Kim, Y.Jeon, B. Jeon (LG Electronics) |
| JCTVC-C219 | m18259 | 2010-10-01 18:37:06 | 2010-10-01 19:25:33 | 2010-10-10 09:36:01 | In-loop reference frame denoising | P. Amon, A. Hutter, E. Wige, A. Kaup (Siemens) |
| JCTVC-C220 | m18260 | 2010-10-01 19:00:04 | 2010-10-03 04:06:06 | 2010-10-14 05:41:05 | TE3: Summary report for inter prediction in HEVC | A. Krutz, T. Sikora (Tech. Univ. Berlin) |
| JCTVC-C221 | m18261 | 2010-10-01 19:03:33 | 2010-10-03 04:06:56 | 2010-10-03 04:06:56 | TE3: Adaptive global motion temporal prediction for HEVC [Withdrawn] | A. Glantz, A. Krutz, T. Sikora (Tech. Univ. Berlin) |
| JCTVC-C222 | m18262 | 2010-10-01 19:08:17 | 2010-10-03 04:08:16 | 2010-10-03 04:08:16 | In-loop filtering using temporal pixel trajectories [Withdrawn] | M. Esche, A. Krutz, A. Glantz, T. Sikora (Tech. Univ. Berlin) |
| JCTVC-C223 | m18263 | 2010-10-01 19:57:24 | 2010-10-02 08:42:57 | 2010-10-09 07:19:50 | TE8 report | G. Martin-Cocher (RIM), M. Budagavi (TI) |
| JCTVC-C224 | m18264 | 2010-10-01 20:18:27 | 2010-10-02 00:45:40 | 2010-10-02 00:45:40 | Frame coding in vertical raster scan order | D.-K. Kwon, H. Kim (TI) |
| JCTVC-C225 | m18265 | 2010-10-01 20:20:29 | 2010-10-07 04:44:52 | 2010-10-07 04:44:52 | TE12: Summary of evaluation of TMuC tools in TE12 | K. McCann (Samsung/Zetacast) |
| JCTVC-C226 | m18266 | 2010-10-01 20:56:12 | 2010-10-02 02:53:22 | 2010-10-12 02:54:47 | Low-complexity configurable transform architecture for HEVC | M. Sadafale, M. Budagavi (TI) |
| JCTVC-C227 | m18267 | 2010-10-01 20:58:29 | 2010-10-02 02:59:47 | 2010-10-05 11:52:28 | Parallelization of HHI_TRANSFORM_CODING | V. Sze, M. Budagavi (TI) |
| JCTVC-C228 | m18268 | 2010-10-01 20:59:54 | 2010-10-02 03:00:47 | 2010-10-02 03:00:47 | A simple cache model for measuring motion compensation bandwidth | M. Budagavi (TI) |
| JCTVC-C229 | m18269 | 2010-10-01 21:05:44 | 2010-10-01 23:49:57 | 2010-10-02 08:18:00 | TE10 subset 2: Cross check result of MediaTek ALF | I. S. Chong, M. Karczewicz |



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| | | | | | | (Qualcomm) |
| JCTVC-C230 | m18270 | 2010-10-01 21:14:28 | 2010-10-02 08:18:44 | 2010-10-06 17:07:18 | TE12: Cross check result of Panasonic's 3-input-ALF | I. S. Chong, M. Karczewicz (Qualcomm) |
| JCTVC-C231 | m18271 | 2010-10-01 21:26:12 | 2010-10-06 16:05:38 | 2010-10-12 17:30:27 | TE12.1: Results for PU based merging | Y. Suzuki, T.K. Tan, F. Bossen (NTT DOCOMO) |
| JCTVC-C232 | m18272 | 2010-10-01 21:39:50 | 2010-10-01 21:41:43 | 2010-10-01 21:41:43 | TE12.7: Verification of JCTVC-C041 (partition based illumination compensation - PBIC) | N. Sprljan, S. Paschalakis, P. Wu (Mitsubishi Electric) |
| JCTVC-C233 | m18273 | 2010-10-01 21:44:07 | 2010-10-02 01:51:49 | 2010-10-02 01:51:49 | TE3 subtest 3: Local intensity compensation (LIC) for inter prediction | N. Sprljan, S. Paschalakis, P. Wu (Mitsubishi Electric) |
| JCTVC-C234 | m18274 | 2010-10-01 22:10:09 | 2010-10-02 10:26:57 | 2010-10-07 07:11:51 | Simplified intra smoothing | Y. Zheng, M. Coban, M. Karczewicz (Qualcomm) |
| JCTVC-C235 | m18276 | 2010-10-01 22:40:05 | 2010-10-01 22:59:24 | 2010-10-02 08:19:17 | TE12: Evaluation of adptive in-loop filter | I. S. Chong, M. Karczewicz (Qualcomm) |
| JCTVC-C236 | m18277 | 2010-10-01 22:49:09 | 2010-10-01 22:51:19 | 2010-10-04 10:31:49 | Report of complexity analysis of geometric partitioning | K. Vermeirsch, J. De Cock, R. Van de Walle (Ghent Univ. - IBBT) |
| JCTVC-C237 | m18278 | 2010-10-01 22:51:51 | 2010-10-02 07:54:20 | 2010-10-02 07:54:20 | Reduced complexity 32Ã—32 transform by coefficient zero-out | J. Sole, R. Joshi, M. Karczewicz (Qualcomm) |
| JCTVC-C238 | m18279 | 2010-10-01 22:53:59 | 2010-10-02 01:19:02 | 2010-10-03 00:49:23 | TE12.8: Results on RDOQ in high efficiency settings | J. Zan, J. Meng, M. T. Islam, D. He (RIM) |
| JCTVC-C239 | m18280 | 2010-10-01 22:57:22 | 2010-10-02 01:58:44 | 2010-10-02 01:58:44 | TE12: Report on interpolation filter: SIFO/DIF | R. Panchal, M. Karczewicz (Qualcomm) |



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| JCTVC-C240 | m18281 | 2010-10-01 22:57:27 | 2010-10-03 05:43:21 | 2010-10-09 14:40:22 | TE3: Cross-check results of local intensity compensation tool from Mitsubishi Electric | D. Karwowski (Poznan Univ. Tech.) |
| JCTVC-C241 | m18282 | 2010-10-01 22:58:59 | 2010-10-02 01:56:58 | 2010-10-02 01:56:58 | TE12: Crosscheck on interpolation filter: SIFO(DIF)/MOMS | R. Panchal, M. Karczewicz (Qualcomm) |
| JCTVC-C242 | m18283 | 2010-10-01 23:01:38 | | | Document registration withdrawn [Withdrawn] | |
| JCTVC-C243 | m18284 | 2010-10-01 23:03:08 | 2011-01-01 23:30:18 (post meeting) | 2011-01-01 23:30:18 (post meeting) | Cross check result of JCTVC-C084 | I. S. Chong, M. Karczewicz (Qualcomm) |
| JCTVC-C244 | m18285 | 2010-10-01 23:06:40 | 2010-10-07 07:06:47 | 2010-10-07 07:10:22 | TE12.3: Report on planar intra prediction | D. Flynn (BBC) |
| JCTVC-C245 | m18286 | 2010-10-01 23:07:35 | 2010-10-02 01:19:38 | 2010-10-09 05:55:24 | TE 8: Cross verification of TI-PCP proposal for significance map | J. Zan, J. Meng, M. T. Islam, D. He (RIM) |
| JCTVC-C246 | m18287 | 2010-10-01 23:25:04 | 2010-10-02 10:22:51 | 2010-10-02 10:22:51 | TE12.8: Cross-verification of partition-based illumination compensation (PBIC) | P. Onno (Canon) |
| JCTVC-C247 | m18288 | 2010-10-01 23:27:35 | 2010-10-05 13:23:28 | 2010-10-05 13:23:28 | TE3 subset 4: Cross-verification on bi/single filter switching in FIF | T. Chujoh, K. Kanou, T. Yamakage (Toshiba) |
| JCTVC-C248 | m18289 | 2010-10-01 23:29:03 | 2010-10-05 03:00:20 | 2010-10-05 03:00:20 | TE12.2: Cross verification on DCT-IF for chroma | T. Chujoh, K. Kanou, T. Yamakage (Toshiba) |
| JCTVC-C249 | m18290 | 2010-10-01 23:35:31 | 2010-10-03 00:51:58 | 2010-10-09 11:58:04 | TE 8: Reports on V2V coding and context modeling by RIM | J. Zan, G. Korodi, J. Meng, M. T. Islam, D. He (RIM) |
| JCTVC-C250 | m18291 | 2010-10-02 00:30:27 | 2010-10-02 09:50:47 | 2010-10-08 09:16:04 | Low complexity adaptive coefficient scanning | M. Coban, R. Joshi, M. Karczewicz (Qualcomm) |



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| JCTVC-C251 | m18292 | 2010-10-02 00:37:22 | 2010-10-02 10:53:45 | 2010-10-12 03:39:56 | Overlapped block motion compensation in TMuC | P. Chen, R. Panchal, W.-J. Chien, M. Karczewicz (Qualcomm) |
| JCTVC-C252 | m18293 | 2010-10-02 00:47:24 | 2010-10-03 03:54:18 | 2010-10-03 03:54:18 | TE 12: Report on evaluation of internal bit depth increase and transform precision extension | R. Joshi, M. Karczewicz (Qualcomm) |
| JCTVC-C253 | m18294 | 2010-10-02 01:39:31 | 2010-10-02 09:24:39 | 2010-10-06 22:38:38 | Encoder speedup for bidirectional averaging with rounding control | R. Panchal, M. Karczewicz, P. Chen (Qualcomm) |
| JCTVC-C254 | m18295 | 2010-10-02 02:00:27 | 2010-10-02 09:25:30 | 2010-10-02 09:25:30 | Test result of SIFO for sequencs with illumination change | R. Panchal, M. Karczewicz (Qualcomm) |
| JCTVC-C255 | m18296 | 2010-10-02 02:28:42 | 2010-10-02 03:02:13 | 2010-10-12 04:50:35 | DCT+Hadamard low complexity large transform for Inter coding | M. Budagavi, A. Gupte (TI) |
| JCTVC-C256 | m18297 | 2010-10-02 02:45:47 | 2010-10-02 09:51:24 | 2010-10-02 09:51:24 | New results for entropy slices for highly parallel coding | K. Misra, J. Zhao, A. Segall (SHARP) |
| JCTVC-C257 | m18298 | 2010-10-02 02:46:40 | 2010-10-02 10:57:46 | 2010-10-11 06:11:14 | On motion vector competition | Y. Su, A. Segall (SHARP) |
| JCTVC-C258 | m18299 | 2010-10-02 03:04:08 | 2010-10-02 03:31:04 | 2010-10-06 11:36:01 | TE 12: Evaluation of transform skip flag (RQT_ROOT) | W.-J. Chien, P. Chen, M. Karczewicz (Qualcomm) |
| JCTVC-C259 | m18300 | 2010-10-02 03:05:04 | 2010-10-02 03:13:09 | 2010-10-02 03:13:09 | TE12: Results for experiments on Max CU size | Y. Yu, K. Panusopone, L. Wang, S.-T. Hsiang, F. Ishtiaq (Motorola) |
| JCTVC-C260 | m18301 | 2010-10-02 03:06:18 | 2010-10-02 03:14:03 | 2010-10-10 11:29:44 | Flexible picture partitioning | K. Panusopone, X. Fang, L. Wang (Motorola) |
| JCTVC-C261 | m18302 | 2010-10-02 03:06:32 | 2010-10-03 05:44:33 | 2010-10-03 05:44:33 | TE4: Summary of TE4 on variable length coding | X. Wang (Qualcomm) |



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| JCTVC-C262 | m18303 | 2010-10-02 03:08:46 | 2010-10-03 05:45:53 | 2010-10-09 04:54:19 | TE4: Report on VLC for coded block flag | X. Wang, M. Karczewicz, W.-J. Chien (Qualcomm) |
| JCTVC-C263 | m18304 | 2010-10-02 03:09:58 | 2010-10-03 05:47:05 | 2010-10-06 17:21:25 | Improvements on VLC | M. Karczewicz, W.-J. Chien, X. Wang (Qualcomm) |
| JCTVC-C264 | m18305 | 2010-10-02 03:16:48 | 2010-10-02 03:29:46 | 2010-10-02 10:34:33 | TE 12: Evaluation of block merging (MRG) | W.-J. Chien, P. Chen, M. Karczewicz (Qualcomm) |
| JCTVC-C265 | m18306 | 2010-10-02 03:19:13 | 2010-10-02 03:29:23 | 2010-10-02 10:34:04 | TE 12: Evaluation of adaptive motion vector resolution (AMVRES) | W.-J. Chien, P. Chen, M. Karczewicz (Qualcomm) |
| JCTVC-C266 | m18307 | 2010-10-02 03:21:29 | 2010-10-02 03:31:41 | 2010-10-06 10:47:35 | TE1: Cross-check result of DMVD proposal from JCTVC-C138 (JVC/Kenwood) | W.-J. Chien, P. Chen, M. Karczewicz (Qualcomm) |
| JCTVC-C267 | m18308 | 2010-10-02 03:24:29 | 2010-10-02 03:28:08 | 2010-10-02 03:28:08 | Test results of transform skip flag and phase 2 VLC integration | W.-J. Chien, P. Chen, X. Wang, M. Karczewicz (Qualcomm) |
| JCTVC-C268 | m18310 | 2010-10-02 04:32:25 | 2010-10-02 07:50:50 | 2010-10-02 07:50:50 | TE12: Report on evaluation of MDDT and ROT | R. Joshi, M. Coban, M. Karczewicz (Qualcomm) |
| JCTVC-C269 | m18312 | 2010-10-02 04:45:57 | 2010-10-03 05:48:12 | 2010-10-10 11:34:29 | A study on the impact of intra smoothing | A. Tabatabai, C. Auyeung, E. Maani, T. Suzuki (Sony) |
| JCTVC-C270 | m18313 | 2010-10-02 04:46:40 | 2010-10-02 04:54:43 | 2010-10-13 18:24:09 | TE6.a: Report of line-based coding | X. Peng, J. Xu, F. Wu (Microsoft) |
| JCTVC-C271 | m18314 | 2010-10-02 04:47:48 | 2010-10-02 06:15:55 | 2010-10-02 06:15:55 | TE6: Cross-verification of HiSilicon's short distance intra prediction by Microsoft | X. Peng, J. Xu (Microsoft) |



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| JCTVC-C272 | m18315 | 2010-10-02 04:48:39 | 2010-10-09 03:24:49 | 2010-10-09 03:24:49 | TE6: Cross-verification of MediaTek's overlapped block intra prediction by Microsoft | X. Peng, J. Xu (Microsoft) |
| JCTVC-C273 | m18316 | 2010-10-02 04:49:20 | 2010-10-02 05:11:08 | 2010-10-13 18:19:13 | TE10 subset 1: Report of content-adaptive de-blocking | Z. Xiong, X. Sun, J. Xu (Microsoft) |
| JCTVC-C274 | m18317 | 2010-10-02 04:49:37 | 2010-10-02 05:17:32 | 2010-10-09 03:37:03 | TE10 subset 1: Cross- verification of NEC's joint deblocking-debanding filter by Microsoft | X. Xiong, J. Xu (Microsoft) |
| JCTVC-C275 | m18318 | 2010-10-02 04:49:53 | 2010-10-02 05:20:47 | 2010-10-13 19:28:30 | Improve intra frame coding by PU/TU reordering | X. Peng, J. Xu, F. Wu (Microsoft) |
| JCTVC-C276 | m18319 | 2010-10-02 04:50:06 | 2010-10-02 08:12:20 | 2010-10-13 18:15:04 | Screen content coding results using TMuC | C. Lan, J. Xu, F. Wu (Microsoft), G. Shi (Xidian Univ.) |
| JCTVC-C277 | m18320 | 2010-10-02 04:50:20 | 2010-10-02 05:34:44 | 2010-10-13 19:33:57 | Redundancy reduction in Cbf and merge coding | B. Li, J. Xu, F. Wu, G. J. Sullivan (Microsoft), H. Li (Univ. Sci. Tech China) |
| JCTVC-C278 | m18321 | 2010-10-02 04:50:32 | 2010-10-02 05:38:36 | 2010-10-13 19:34:27 | Redundancy reduction in B-frame coding at temporal level zero | B. Li, J. Xu, G. J. Sullivan, F. Wu (Microsoft), H. Li (Univ. Sci. Tech China) |
| JCTVC-C279 | m18322 | 2010-10-02 05:48:31 | 2010-10-03 00:53:15 | 2010-10-03 00:53:15 | Opportunistic parallel V2V decoding | D. He, G. Korodi, E.-h. Yang, G. Martin-Cocher (RIM) |
| JCTVC-C280 | m18323 | 2010-10-02 06:52:21 | 2010-10-02 07:00:55 | 2010-10-05 08:52:33 | TE8: Crosscheck result of the transcoder for JCTVC-B034 source selection for V2V entropy coding in HEVC | Y.-L. Chang, Y.-W. Huang, S. Lei (MediaTek) |
| JCTVC-C281 | m18324 | 2010-10-02 07:32:11 | 2010-10-02 10:29:00 | 2010-10-07 01:38:00 | TE12: Evaluation of fast adaptive intra smoothing | M. Coban, Y. Zheng, M. Karczewicz (Qualcomm) |
| JCTVC-C282 | m18325 | 2010-10-02 08:15:22 | 2010-10-03 05:49:29 | 2010-10-08 05:51:11 | TE3 subtest 1: Cross-check of results from LG | M. Tok, A. Glantz, A. Krutz, T. Sikora (Tech. Univ. Berlin) |



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| JCTVC-C283 | m18326 | 2010-10-02 09:14:33 | 2010-10-02 10:03:32 | 2010-10-02 10:03:32 | Region of block based dynamic video processing for HEVC | A. Paul (Hanyang Univ. / NCKU) |
| JCTVC-C284 | m18327 | 2010-10-02 09:18:13 | 2010-10-08 14:05:26 | 2010-10-08 14:05:26 | TE9-2.1 Report on forced RQT split according to PUs (Sharp, Microsoft) | A. Segall (Sharp), J. Xu (Microsoft) |
| JCTVC-C285 | m18328 | 2010-10-02 09:32:20 | 2010-10-02 10:31:28 | 2010-10-02 10:31:28 | Modified uni-directional inter prediction in generalized P and B pictures | W.-J. Chien, P. Chen, X. Wang, M. Karczewicz (Qualcomm) |
| JCTVC-C286 | m18329 | 2010-10-02 10:20:23 | 2010-10-02 10:23:03 | 2010-10-02 10:23:03 | TE12.2: Technicolor & INRIA report on AMP evaluation | E. Francois (Technicolor), L. Guillo (INRIA) |
| JCTVC-C287 | m18330 | 2010-10-02 12:56:27 | 2010-10-04 12:56:12 | 2010-10-08 08:37:15 | Cross-check of encoder speedup for bidirectional averaging with rounding control | B. Bross (Fraunhofer HHI) |
| JCTVC-C288 | m18331 | 2010-10-02 13:14:36 | 2010-10-04 10:50:06 | 2010-10-04 10:50:06 | TE4: Verification results of JCTVC-C262 | T. Yamakage (Toshiba) |
| JCTVC-C289 | m18332 | 2010-10-02 13:40:03 | 2010-10-02 13:43:12 | 2010-10-07 03:38:46 | TE11: Report on experiment 3.1.a: Disabling MV competition | J. Jung, G. Clare, S. Pateux (Orange Labs) |
| JCTVC-C290 | m18333 | 2010-10-02 13:48:00 | 2010-10-02 13:49:40 | 2010-10-07 03:41:06 | TE11: Report on experiment 3.2.b: MV-Competition on Inter, Skip and Direct modes | J. Jung, G. Clare, S. Pateux (Orange Labs) |
| JCTVC-C291 | m18334 | 2010-10-02 13:53:14 | 2010-10-02 13:55:12 | 2010-10-07 07:52:39 | TE11: Report on experiment 3.3.b: â€˜temporally oriented' set of predictors for MV-Competition | J. Jung, G. Clare, S. Pateux (Orange Labs) |
| JCTVC-C292 | m18335 | 2010-10-02 13:57:10 | 2010-10-05 15:20:38 | 2010-10-05 15:20:38 | TE11: Verification of experiment 3.2.d by NTT DOCOMO | J. Jung, G. Clare, S. Pateux (Orange Labs) |
| JCTVC-C293 | m18336 | 2010-10-02 13:59:55 | 2010-10-02 14:08:42 | 2010-10-08 13:25:52 | TE11: Summary report for TE11 on motion vector coding | J. Jung (Orange Labs) |
| JCTVC-C294 | m18337 | 2010-10-03 03:59:52 | | | Level limits for Progressive High Profile [Withdrawn from JCT-VC] | A. Wells (Ambarella), C. Fogg (Harmonic) |
| JCTVC-C295 | m18340 | 2010-10-03 11:46:12 | 2010-10-11 17:43:31 | 2010-10-11 17:44:37 | Re-compensation based on partial coefficients | H. Zhu (Zhu) |
| JCTVC-C296 | m18341 | 2010-10-03 | 2010-10-05 | 2010-10-07 | Decoding improvement on the PA-Coder | H. Zhu (Zhu) |



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| | | 11:47:37 | 14:10:07 | 20:00:59 | | |
| JCTVC-C297 | m18344 | 2010-10-03 14:49:12 | 2010-10-06 19:26:48 | 2010-10-11 05:21:20 | Cross-verification of JCTVC-C213: additional results for combined intra prediction | W.-J. Han (Samsung) |
| JCTVC-C298 | m18411 | 2010-10-04 16:37:29 | 2010-10-07 17:04:02 | 2010-10-07 17:04:02 | TE12.4 Cross-check of unified MDDT/ROT | T. Davies, D. Flynn (BBC) |
| JCTVC-C299 | m18423 | 2010-10-04 17:11:53 | 2010-10-04 17:17:59 | 2010-10-04 17:17:59 | UK National Body comments on HEVC Timescales | UKNB of WG11 |
| JCTVC-C300 | m18491 | 2010-10-05 01:59:03 | 2010-10-07 02:13:29 | 2010-10-08 22:39:09 | High-efficiency entropy coding simplifications | V. Sze, M. Budagavi (TI) |
| JCTVC-C301 | m18516 | 2010-10-05 11:55:43 | 2010-10-05 13:14:49 | 2010-10-05 13:14:49 | Geometry motion partition | P. Chen, L. Guo, M. Karczewicz (Qualcomm) |
| JCTVC-C302 | m18517 | 2010-10-05 12:12:15 | 2010-10-05 18:35:46 | 2010-10-12 03:33:48 | Improved intra smoothing for UDI and new AIS fast mode | T. Nguyen (Fraunhofer HHI) |
| JCTVC-C303 | m18522 | 2010-10-05 15:04:43 | 2010-10-06 03:23:58 | 2010-10-06 03:23:58 | Geometry adaptive block partitioning (GEO) cross-check | E. Francois, P. Bordes (Technicolor) |
| JCTVC-C304 | m18537 | 2010-10-06 10:03:34 | 2010-10-06 10:41:23 | 2010-10-12 04:52:10 | Showing the possibility of fast CABAC | H.-Joong Kim, X. Qu (Korea Univ.), W.-J. Han (Samsung) |
| JCTVC-C305 | m18544 | 2010-10-06 16:54:17 | 2010-10-08 09:09:59 | 2010-10-08 09:09:59 | TE7: Results for Simplification of MDDT Transform | W. Ding, Y. Shi, B. Yin (Beijing Univ. Tech) |
| JCTVC-C306 | m18546 | 2010-10-06 22:48:03 | 2010-10-06 22:53:07 | 2010-10-06 22:53:07 | Investigations for representing rectangular blocks using the merging concept | H. Schwarz, D. Marpe, T. Wiegand (Fraunhofer HHI) |
| JCTVC-C307 | m18548 | 2010-10-07 00:59:51 | 2010-10-07 01:05:51 | 2010-10-10 11:18:03 | Cross Verification of Low Complexity Adaptive Coefficient Scanning | J. Zan, J. Meng, M. T. Islam, D. He (RIM) |
| JCTVC-C308 | m18556 | 2010-10-08 10:46:20 | 2010-12-03 09:28:17 (post meeting) | 2010-12-03 09:28:17 (post meeting) | Cross verification of MV Coding Proposal by JCTVC-C293 | K. Sato (Sony) |



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| JCTVC-C309 | m18557 | 2010-10-08 10:49:19 | 2010-12-03 09:28:59 (post meeting) | 2010-12-03 09:28:59 (post meeting) | Cross verification of DCT-IF for chroma | T. Suzuki (Sony) |
| JCTVC-C310 | m18568 | 2010-10-09 05:01:43 | 2010-10-09 05:19:21 | 2010-10-09 05:19:21 | TE7: Summary report for MDDT Simplification | R. Cohen (Merl), C. Yeo (I2R), R. Joshi (Qualcomm) |
| JCTVC-C311 | m18569 | 2010-10-09 06:24:29 | 2010-10-09 07:20:20 | 2010-10-12 03:11:10 | Fast intra encoding for fixed maximum depth of transform quadtree | B. Bross, H. Kirchhoffer, H. Schwarz, T. Wiegand (Fraunhofer HHI) |
| JCTVC-C312 | m18571 | 2010-10-09 12:04:06 | 2010-10-09 13:07:43 | 2010-10-13 11:16:05 | Cross-verification of JCTVC-C311: Fast intra encoding for fixed maximum depth of transform quadtree | W.-J. Han (Samsung) |
| JCTVC-C313 | m18572 | 2010-10-09 19:30:20 | 2010-10-09 21:10:33 | 2010-10-09 21:10:33 | TE8: Crosscheck Result of the Transcoder of JCTVC-B034 for V2V Entropy Coding in HEVC | Y. Zheng, R. Joshi, M. Coban, M. Karczewicz (Qualcomm) |
| JCTVC-C314 | m18573 | 2010-10-10 02:39:08 | 2010-10-11 09:51:21 | 2010-10-11 11:00:22 | Verification results of Samsung's proposal JCTVC-C206 | J. Kim, J. Park, B. Jeon (LG Electronics) |
| JCTVC-C315 | m18581 | 2010-10-11 06:39:54 | 2010-10-11 06:43:38 | 2010-10-11 06:43:38 | On the computation of PSNR and BD-Rate | D. Hoang (Zenverge) |
| JCTVC-C316 | m18583 | 2010-10-11 12:55:37 | 2010-10-11 18:26:13 | 2010-10-11 18:26:13 | Verification Results of Simplified Intra Smoothing (JCTVC-C234) | T. Yamakage (Toshiba) |
| JCTVC-C317 | m18584 | 2010-10-12 02:53:18 | 2010-10-12 03:05:50 | 2010-10-12 03:06:10 | Breakout Report on Interpolation Filters | K. Ugur (BoG coordinator) |
| JCTVC-C318 | m18586 | 2010-10-12 15:15:33 | 2010-10-12 15:19:57 | 2010-10-12 15:19:57 | TMuC text on max CU size seems broken | R. Sjöberg (Ericsson) |
| JCTVC-C319 | m18590 | 2010-10-14 03:28:32 | 2010-10-14 03:41:23 | 2010-10-14 19:05:29 | BoG report: Residual quadtree structure | T. Wiegand, H. Schwarz, B. Bross, A. Fuldseth, X. Wang, W.-J. Han (BoG coordinators) |



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| JCTVC-C320 | m18597 | 2010-10-14 10:34:43 | 2010-10-14 10:42:10 | 2010-10-14 10:42:10 | TE12: Summary of results of evaluation of TMuC tools in TE12 | K. McCann (TE coordinator) |
| JCTVC-C400 | m18617 | 2010-10-21 07:41:14 | | | Meeting report of the third meeting of the Joint Collaborative Team on Video Coding (JCT-VC), Guangzhou, CN, 7-28 October, 2010 | G. J. Sullivan, J.-R. Ohm (chairs) |
| JCTVC-C401 | m18589 | 2010-10-14 02:42:48 | 2010-10-14 02:46:52 | 2010-10-15 04:39:15 | The process of Test Model development for the HEVC initiative | G. Sullivan, J.-R. Ohm (chairs) |
| JCTVC-C402 | m18618 | 2010-10-21 07:42:48 | | | High Efficiency Video Coding (HEVC) Test Model 1 (HM 1) Encoder Description | K. McCann, B. Bross, S. Sekiguchi (editors) |
| JCTVC-C403 | m18619 | 2010-10-21 07:44:39 | | | High Efficiency Video Coding (HEVC) text specification Working Draft 1 | T. Wiegand, W.-J. Han, J.-R. Ohm, G. J. Sullivan (editors) |
| JCTVC-C404 | m18594 | 2010-10-14 06:58:49 | 2010-10-15 06:12:59 | 2010-10-15 17:10:22 | HEVC software guidelines | K. Sühring, D. Flynn, F. Bossen (on behalf of JCT-VC) |
| JCTVC-C405 | m18616 | 2010-10-15 08:08:05 | 2010-10-15 08:35:05 | 2010-11-01 09:34:49 | Summary of HEVC working draft 1 and HEVC test model (HM) | T. K. Tan, G. J. Sullivan, J.-R. Ohm (on behalf of JCT-VC) |
| JCTVC-C500 | m18607 | 2010-10-15 02:59:12 | 2010-10-15 03:08:44 | 2010-10-15 03:08:44 | Common test conditions and software reference configurations | F. Bossen (on behalf of JCT-VC) |
| JCTVC-C501 | m18604 | 2010-10-15 02:36:59 | 2010-10-15 02:38:30 | 2010-10-30 06:18:41 | Description of Core Experiment 1: Decoder-Side Motion Vector Derivation | Y.-J. Chiu, H. Yu, Y.-W. Huang, S. Sekiguchi (CE coordinators) |
| JCTVC-C502 | m18602 | 2010-10-15 01:57:36 | 2010-10-15 01:59:01 | 2010-10-30 16:03:26 | Description of Core Experiment 2: Flexible Motion Partitioning | E. Francois, P. Chen, X. Zheng (CE coordinators) |
| JCTVC-C503 | m18613 | 2010-10-15 03:43:20 | 2010-10-15 03:45:12 | 2010-10-30 04:44:05 | Description of Core Experiment 3: Interpolation Filtering for MC (Luma) | T. Chujoh (CE coordinator) |
| JCTVC-C504 | m18603 | 2010-10-15 | 2010-10-15 | 2010-11-12 | Description of Core Experiment 4: Interpolation for MC | E. Alshina, Y.-L. |



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|---|---|---|---|---|---|---|
| | | 02:20:32 | 02:20:46 | 06:03:36 | (Chroma) | Lee, P. Chen, H. Lakshman (CE coordinators) |
| JCTVC-C505 | m18609 | 2010-10-15 03:21:14 | 2010-10-15 03:25:06 | 2010-11-02 00:25:34 | Description of Core Experiment 5: Low Complexity Entropy Coding Improvements | X. Wang (CE coordinator) |
| JCTVC-C506 | m18608 | 2010-10-15 03:20:50 | 2010-10-15 03:22:43 | 2010-11-01 23:01:48 | Description of Core Experiment 6: Intra Prediction Improvement | A Tabatabai (CE coordinator) |
| JCTVC-C507 | m18601 | 2010-10-14 20:02:08 | 2010-10-14 20:05:45 | 2010-11-02 21:27:32 | Description of Core Experiment 7: Alternative Transforms | R. Cohen, C. Yeo, R. Joshi (CE coordinators) |
| JCTVC-C508 | m18612 | 2010-10-15 03:43:14 | 2010-10-15 03:44:26 | 2010-10-30 04:12:21 | Description of Core Experiment 8: In-loop filtering | T. Yamakage, T. Chujoh, Y. W. Huang, K. Chono, I.S. Chong, T. Yamamoto, J. Lim, B. Jeon, J. Xu, M. Narroschke (CE coordinators) |
| JCTVC-C509 | m18600 | 2010-10-14 17:55:12 | 2010-10-14 17:57:17 | 2010-11-19 15:51:40 | Description of Core Experiment 9: Motion Vector Coding | J. Jung, B. Bross (CE coordinators) |
| JCTVC-C510 | m18606 | 2010-10-15 02:58:50 | 2010-10-15 03:08:27 | 2010-11-01 11:10:43 | Description of Core Experiment 10: Number of Intra Prediction Directions | K. Sugimoto (CE coordinator) |
| JCTVC-C511 | m18610 | 2010-10-15 03:35:54 | 2010-10-15 03:37:03 | 2010-11-03 22:40:47 | Description of Core Experiment 11: Coefficient Scanning and Coding | V. Sze, K. Panusopone, J. Chen, T. Nguyen, M. Coban (CE coordinators) |
| JCTVC-C512 | m18605 | 2010-10-15 02:37:32 | 2010-10-15 02:38:58 | 2010-10-30 01:59:59 | Description of Core Experiment 12: Adaptive Motion Vector Resolution | W.-J. Chien (CE coordinator) |
| JCTVC-C513 | m18611 | 2010-10-15 03:41:16 | 2010-10-15 03:47:00 | 2010-11-05 22:06:15 | Description of Core Experiment 13: Intra Smoothing | M.Coban, B. Bross, J. Chen (CE coordinators) |



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# 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 244 in total), were as follows:

1. Alshina, Elena (Samsung)
2. Amon, Peter (Siemens)
3. Andersson, Kenneth (Ericsson)
4. Aoki, Hirofumi (NEC)
5. Asai, Kohtaro (Mitsubishi Electric)
6. Au, Jicheng (MediaTek)
7. Au, Oscar (Hong Kong Univ. Sci. & Tech.)
8. Auyeung, Cheung (Sony)
9. Bandoh, Yukihiro (NTT)
10. Bang, Gun (ETRI)
11. Barbarien, Joeri (Vrije Univ. Brussels)
12. Bici, Oguz (Nokia)
13. Bivolarsky, Lazar (Skype Technologies)
14. Boitard, Ronan (INRIA)
15. Bopardikar, Rajendra (Intel)
16. Bossen, Frank (DoCoMo USA Labs)
17. Boyce, Jill (Vidyo)
18. Bross, Benjamin (Fraunhofer HHI)
19. Brylants, Tim (Vrije Univ. Brussel)
20. Budagavi, Madhukar (Texas Instruments Inc)
21. Cao, Xiaoran (Tsinghua Univ.)
22. Chen, Jianle (Samsung)
23. Chen, Lulin (Harmonic)
24. Chen, Sijia (Cisco Systems)
25. Chien, Wei-Jung (Qualcomm)
26. Chiu, Yi-Jen (Intel)
27. Cho, In Joon (KBS)
28. Cho, Jaehee (Sejong Univ.)
29. Choi, Haechul (Hanbat Univ.)
30. Choi, Jin Soo (ETRI)
31. Choi, Kiho (Hanyang Univ.)
32. Chong, In Suk (Qualcomm)
33. Chono, Keiichi (NEC)
34. Chujoh, Takeshi (Toshiba)
35. Clare, Gordon (Orange Labs)
36. Coban, Muhammed (Qualcomm)
37. Cohen, Robert (Mitsubishi Electric)
38. Davies, Thomas (BBC R&D)
39. De Cock, Jan (Ghent Univ. - IBBT)
40. Ding, Wenping (Beijing Univ. Tech.)
41. Dong, Jie (Chinese Univ. Hong Kong)
42. Drugeon, Virginie (Panasonic)
43. Fan, Xiaopeng (Harbin / HKUST)
44. Fernandes, Felix (Samsung)
45. Flynn, David (BBC)
46. Fogg, Chad (Harmonic)
47. François, Edouard (Technicolor)
48. Fujibayashi, Akira (NTT DoCoMo)
49. Fukushima, Shigeru (JVC Kenwood)
50. Fuldseth, Arild (Tandberg)
51. Glantz, Alexander (Tech. Univ. Berlin)
52. Gu, Chenchen (Tencent)
53. Guillo, Laurent (INRIA)
54. Guo, Xun (MediaTek)
55. Han, Jong-Ki (Sejong Univ.)
56. Han, Woo-Jim (Samsung)
57. He, Dake (RIM)
58. He, Yun (Tsinghua Univ.)
59. Heo, Youngsu (Kyunghee Univ.)
60. Ho, Yo-Sung (GIST)
61. Hoang, Dzung (Zenverge, Inc.)
62. Hong, Soongi (Yonsei Univ.)
63. Hong, Sung-Wook (Sejong Univ.)
64. Hong, Yingjie (ZTE)
65. Horowitz, Michael (Vidyo, Inc.)
66. Hsiang, Shih-Ta (Motorola, Inc.)
67. Hsu, Chih-Wei (MediaTek)
68. Huang, Yu-Wen (MediaTek)
69. Huo, Junyan (Xi'dian Univ.)
70. Ichigaya, Atsuro (NHK)
71. Ishtiaq, Faisal (Motorola Inc.)
72. Jacobs, Marc (Vrije Univ. Brussel)
73. Jang, Euy-Doc (Korea Aerospace Univ.)
74. Jeon, Byeong Moon (LG)



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75. Jeon, Byeungwoo (Sungkyunkwan Univ.)
76. Jeon, Yong-Joon (LG Electronics)
77. Jeong, Seyoon (ETRI)
78. Jin, Xin (Waseda Univ.)
79. Jung, Ji Wook (LG)
80. Jung, Joël (Orange Labs)
81. Jung, Tae-Young (Hanyang Univ.)
82. Kang, Jung Won (ETRI)
83. Karczewicz, Marta (Qualcomm)
84. Kazui, Kimihiko (Fujitsu)
85. Kim, Hae Kwang (Sejong Univ.)
86. Kim, Hui Yong (ETRI)
87. Kim, Hyun-Dong (Sejong Univ.)
88. Kim, Il Koo (Samsung)
89. Kim, In Kwon (Galaxia Commun.)
90. Kim, Jae-Gon (Korea Aerosp. Univ.)
91. Kim, Jeong-Pil (Sejong Univ.)
92. Kim, Jongho (Yonsei Univ.)
93. Kim, Kibaek (Hanyang Univ.)
94. Kim, Kyungyong (Kwangwoon Univ.)
95. Kim, Munchurl (KAIST)
96. Kim, Seong Hoon (Galaxia Commun.)
97. Kim, Seongwan (Yonsei Univ.)
98. Klomp, Sven (Leibniz Univ. Hannover)
99. Kogure, Takuyo (Panasonic )
100. Kondo, Kenji (Sony)
101. Koyama, Jumpei (Fujitsu)
102. Krutz, Andreas (Tech. Univ. Berlin)
103. Lai, Polin (Wang) (Samsung)
104. Lainema, Jani (Nokia)
105. Lakshman, Haricharan (Fraunhofer HHI)
106. Laroche, Guillaume (Canon)
107. Lee, Ju Ock (Sejong Univ.)
108. Lee, Sangyoun (Yonsei Univ.)
109. Lee, Shanfu (Huawei)
110. Lee, Yoomjim (Kyunghee Univ.)
111. Lee, Yung-Lyul (Sejong Univ.)
112. Lei, Shawmin (MediaTek)
113. Li, Guichun (Huawei)
114. Li, Junlin (Cisco Systems)
115. Li, Ming (ZTE)
116. Li, Wei (Xi'dian Univ.)
117. Li, Zhengguo (I2R)
118. Lim, Chongsoon (Panasonic Singapore Labs)
119. Lim, Jaehyun (LG Electronics)
120. Lim, Jeongyeon (SK Telecom)
121. Lim, Sung-Chang (ETRI)
122. Lim, Woong (Kwangwoon Univ.)
123. Lin, Sixin (Huawei)
124. Lin, Yongbing (Huawei)
125. Ling, Nam (Santa Clara Univ.)
126. Liu, Hui (Cisco Systems)
127. Liu, Lingzhi (Huawei / Hisilicon)
128. Liu, Yu (ASTRI)
129. Lopez, Patrick (Technicolor)
130. Luthra, Ajay (Motorola)
131. Ma, Ran (Shanghai Univ.)
132. Ma, Siwei (Peking Univ.)
133. Mao, Xunan (Tencent)
134. Marpe, Detlev (Fraunhofer HHI)
135. Martin-Cocher, Gaëlle (RIM)
136. Matsuo, Shohei (NTT)
137. McCann, Ken (Zetacast / Samsung)
138. Mochizuki, Seiji (Renesas)
139. Moon, Joo-Hee (Sejong Univ.)
140. Mrak, Marta (BBC)
141. Murakami, Tokumichi (Mitsubishi Electric)
142. Murakami, Tomokazu (Hitachi)
143. Narroschke, Matthias (Panasonic R&D Germany)
144. Nishi, Takahiro (Panasonic)
145. Oh, Seoung-Jun (Kwangwoon Univ.)
146. Ohm, Jens-Rainer (RWTH Aachen Univ.)
147. O'loughlin, Daniel (Research in Motion)
148. Onno, Patrice (Canon)
149. Panusopone, Krit (Motorola)
150. Park, Gwang Hoon (Kyunghee Univ.)
151. Park, Hyoungmee (Sejong Univ.)
152. Park, Jeonghoon (Samsung)
153. Park, Seungwook (LG)
154. Park, Un-Ki (Korea Aerospace Univ.)
155. Paschalakis, Stavros (Mitsubishi Electric R&D Europe B.V.)
156. Peng, Wen-Hsiao (NCTU/ITRI)
157. Qu, Xiaochao (Korea Univ.)
158. Raad, Mohamad (RaadTech Consulting)
159. Ralston, John (Droplet Tech)
160. Ridge, Justin (Nokia)
161. Sakaida, Shinichi (NHK)
162. Sampedro, Jesus (Polycom)


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163. Sasai, Hisao (Panasonic)
164. Sato, Kazushi (Sony)
165. Saxena, Ankur (Samsung Telecom. America)
166. Schelkens, Peter (Vrije Univ. Brussel)
167. Segall, Andrew (Sharp)
168. Sekiguchi, Shun-ichi (Mitsubishi Electric)
169. Senzaki, Kenta (NEC)
170. Seo, Chan-Won (Sejong Univ.)
171. Shen, Bazhong (Broadcom)
172. Shibahara, Youji (Panasonic)
173. Shima, Masato (Canon)
174. Shimizu, Shinya (NTT)
175. Shiodera, Taichiro (Toshiba)
176. Sim, Donggyu (Kwangwoon Univ.)
177. Sjöberg, Rickard (Ericsson)
178. Song, Jin (Huawei)
179. Sprljan, Nikola (Mitsubishi Electric R&D Centre Europe)
180. Sühring, Karsten (Fraunhofer HHI)
181. Sugimoto, Kazuo (Mitsubishi Electric)
182. Sugio, Toshiyasu (Panasonic)
183. Suh, Jung Suk (Samsung)
184. Sullivan, Gary (Microsoft)
185. Sun, Huifang (Mitsubishi Electric)
186. Suzuki, Teruhiko (Sony)
187. Sze, Vivienne (Texas Instruments)
188. Tabatabai, Ali (Sony Electronics)
189. Takamura, Seishi (NTT)
190. Tan, Thiow Keng (NTT DoCoMo)
191. Tan, Yih Han (I2R)
192. Tanizawa, Akiyuki (Toshiba)
193. Temmermom, Frederik (Vrije Univ. Brussel)
194. Tonomura, Yoshide (NTT)
195. Topiwala, Pankaj (FastVDO)
196. Tsukagushi, Ikuo (Sony)
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198. Ueda, Motoharu (JVC Kenwood)
199. Ugur, Kemal (Nokia)
200. Vermeirsch, Kenneth (Ghent Univ. -- IBBT)
201. Wahadaniah, Viktor (Panasonic Singapore Labs)
202. Wan, Wade (Broadcom)
203. Wang, David (Polycom)
204. Wang, Pulin (Huawei)
205. Wang, Xianglin (Qualcomm)
206. Wang, Ye-Kui (Huawei)
207. Wedi, Thomas (Panasonic)
208. Wegner, Krzysztof (Poznań Univ. Tech.)
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215. Wu, Zhixiong (OKI)
216. Xu, Jizheng (Microsoft)
217. Xu, Lidong (Intel)
218. Xu, Yian (Cisco Systems)
219. Yamakage, Tomoo (Toshiba)
220. Yamamoto, Tomoyuki (Sharp)
221. Yang, Fuzheng (Xi'dian Univ.)
222. Yang, Haitao (Huawei)
223. Yang, Hongzhang (Freescale Semiconductor)
224. Yang, Jungyoup (Sungkyunkwan Univ.)
225. Yang, Ming Yuan (Huawei)
226. Yang, Zhijie (Broadcom)
227. Ye, Yan (Dolby Labs)
228. Yea, Sehoon (LG)
229. Yeo, Chuohao (I2R)
230. Yoon, Daeil (Sejong Univ.)
231. Yoshino, Tomonobu (KDDI)
232. Yu, Haoping (Huawei)
233. Yu, Lu (Zhejiang Univ.)
234. Yu, Yong (Broadcom)
235. Yuan, Yuan (Tsinghua Univ.)
236. Zhang, Li (Peking Univ.)
237. Zhang, Louis (AMD)
238. Zhang, Wen (ZTE)
239. Zhao, Haiwu (Shanghai Univ.)
240. Zhao, Qing Yi (Tencent)
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