Joint Collaborative Team on Video Coding (JCT-VC)
of ITU-T SG16 WP3 and ISO/IEC JTC1/SC29/WG11
2nd Meeting: Geneva, CH, 21-28 July, 2010

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Title: **Meeting report of the second meeting of the Joint Collaborative Team on Video Coding (JCT-VC), Geneva, CH, 21-28 July, 2010**

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Author(s) or Contact(s):

Gary Sullivan
Microsoft Corp.
1 Microsoft Way
Redmond, WA 98052 USA
Tel: +1 425 703 5308
Email: garysull@microsoft.com

Jens-Rainer Ohm
Institute of Communications Engineering
RWTH Aachen University
Melatener Straße 23
D-52074 Aachen
Tel: +49 241 80 27671
Email: ohm@ient.rwth-aachen.de

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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 second meeting during 21-28 July, 2010 at the ITU-T premises in Geneva, CH. 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 11:30 a.m. on Wednesday 21 July. Meeting sessions were held on all days (including weekend days) until the meeting was closed at approximately 11:40 a.m. on Wednesday 28 July. Approximately 220 people attended the JCT-VC meeting, and approximately 120 input documents were discussed. The meeting took place in a co-located fashion with a meeting of ITU-T SG16 – 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 focus of the meeting was to review the work that was performed in the interim period since the first JCT-VC meeting in implementing the Test Model under Consideration (TMuC), review results from Tool Experiments (TE), review technical input documents and define steps towards the establishment of the Test Model (TM) as planned for the third meeting. The review revealed that the current implementation of TMuC software exhibits similar improvement in compression performance as was previously seen from some of the best performing proposals in the CfP results.

The JCT-VC produced three important output documents from the meeting: An updated version of the "Test Model under Consideration" (TMuC) document, a description of encoder techniques for the TMuC design, and a documentation of the default settings of the TMuC software, as to be used in the upcoming TEs. Furthermore, 12 documents describing the planning of TEs were drafted. Among these, TE12, which is intended to evaluate the TMuC on a tool by tool basis, plays the most prominent role for the upcoming TM definition.

For the organization and planning of its future work, the JCT-VC established ten "*Ad Hoc* Groups" (AHGs) to progress the work on particular subject areas. The next JCT-VC meetings will be held during 7-15 October 2010 in Guangzhou, China, and during 20-28 January 2011 in Daegu, Korea, both under the auspices of JTC 1/SC 29/WG 11. The reflector to be used for discussions by the JCT-VC and all of its

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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.

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1.2 Meeting logistics

The JCT-VC meeting sessions began at approximately 11:30 a.m. on Wednesday 21 July. Meeting sessions were held on all days (including weekend days) until the meeting was closed at approximately 11:40 a.m. on Wednesday 28 July. Approximately 220 people attended the JCT-VC meeting, and approximately 120 input documents were discussed. The meeting took place in a co-located fashion with a meeting of ITU-T SG16 – 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://www.itu.int/ITU-T/studygroups/com16/ and http://www.itu.int/events/.

1.3 Primary goals

The primary focus of the meeting was to review the work that was performed in the interim period since the first JCT-VC meeting in implementing the Test Model under Consideration (TMuC), review results from Tool Experiments (TE), review technical input documents and define steps towards the establishment of the Test Model (TM) as planned for the third meeting.

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://ftp3.itu.int/av-arch/jctvc-site/2010_07_B_Geneva/.

The formal deadline for registering and uploading contributions was July 16, 2010. No regular contribution registered prior to the meeting (within number range JCTVC-B020 through JCTVC-B119) was submitted late. Adhoc reports JCTVC-B001, JCTVC-B003 and JCTVC-B006 were not available by the time of the opening of the meeting, but shortly afterwards. There were no objections raised by the group regarding presentation of these late contributions.

Contribution document registrations JCTVC-B052 and JCTVC-B060 were withdrawn (no documents had been provided).

Contribution document registration had been conducted by email to the Chairs, and document registration lists had been sent to the email discussion reflector of the JCT-VC.

The report documents of the previous meeting, particularly the meeting report JCTVC-A200, the Test Report JCTVC-A204 and the TMuC description JCTVC-A205 in the latest version (rev 7) were approved.

1.5 Attendance

The list of participants in the JCT-VC meeting can be found in Annex B of this report.

The meeting was open to those qualified to participate either in ITU-T WP3/16 or ISO/IEC JCT1/SC29/WG11 (including experts who had been personally invited by the Chairs as permitted by ITU-T or ISO/IEC policies).

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

1.6 Agenda

The agenda for the meeting was as follows:

- IPR policy reminder and declarations
- Contribution document allocation
- Reports of Ad Hoc group activities
- Reports of 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 (JVT founding charter)
- http://www.itu.int/ITU-T/dbase/patent/index.html (ITU-T IPR database)
- http://www.itscj.ipsj.or.jp/sc29/29w7proc.htm (SC29 Procedures)

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

1.8 Communication practices

JCT-VC documents had been made available at http://ftp3.itu.int/av-arch/jctvc-site.

These could also be accessed via ftp with the site name ftp3.itu.int, user ID avguest and a password provided upon request by the Chairs. Upon login, documents were then found in the directory "jctvc-site". Uploading of contributions was done by upload via ftp protocol to the "jctvc-site/dropbox" directory using this account ID and password.

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 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 coordinators and AHG chairs.

1.9 Terminology

Some terminology used in this report is explained below:

- **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).
- **R-D**: rate-distortion.
- **RDO**: rate-distortion optimization.
- **JM**: Joint model – the primary software codebase developed for the AVC standard.
- **HEVC**: High Efficiency Video Coding – the video coding standardization initiative under way in the JCT-VC.
- **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.

- **TE**: Tool Experiment – a coordinated experiment

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 and quantity of contributions for the meeting was summarized as follows.

- AHG reports and TE summary reports (12)
- TMuC (4)
- TE1: Decoder-side motion derivation (13)
- TE2: IBDI and memory compression (7)
- TE3: Inter prediction (10)
- TE4: Variable length coding (5)
- Parallel entropy coding (3)
- Intra prediction (18)
- Transforms for Intra (6)
- Large block sizes (3)
- MV prediction and coding (8)
- Loop filtering and AIF (9)
- Quantization (2)
- Application area specific contributions (4)
- Performance measurement and new test material (3)

2 AHG reports

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

JCTVC-B001 [G. Sullivan, J.-R. Ohm (chairs)] AHG report: JCT-VC project management

This document reported on the work of the JCT-VC *ad hoc* group on Project Management, tasked with coordination and reporting on the overall work of the JCT-VC initiative in the interim period since the previous meeting.

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

- The meeting report (JCTVC-A200)
- The subjective testing report (JCTVC-A204)
- Eight versions of the Test Model under Consideration (TMuC, JCTVC-A205)

The various ad hoc groups and tool experiments had made progress and reports 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.

The JCT-VC management had contacted the management level of the parent bodies and all of those who have been involved thus far in the software development work, to determine the appropriate course of action on this topic.

Suggested conclusions on this topic at this stage were described, and were supported by the JCT-VC as a whole, as follows:

- The software will be developed by the standardization organization in a very highly-collaborative fashion, involving a software development effort that is taking place over a significant period of time with a large number of contributors (probably hundreds of individual contributors). It should thus be considered as the output of the standardization development organization rather than as a mere publication of something developed elsewhere in a private fashion. In this regard, it is suggested that making a contribution to the software development effort should be considered essentially equivalent to the way that contributing to the development of the text of a non-software standard is conducted. This manner of work has been expressed by ITU-T (in Recommendation A.1) as follows: "Material such as text, diagrams, etc., submitted as a contribution to the work of the ITU-T is presumed by ITU to have no restrictions in order to permit the normal distribution of this material for discussions within the appropriate groups and possible use, in whole or in part, in any resulting ITU-T Recommendations which are published. By submitting a contribution to ITU-T, authors acknowledge this condition of submission. In addition, authors may state any specific conditions on other uses of their contribution."

- From the perspective of the contributors to the software development effort, the primary concern that has been expressed is to ensure that the act of contributing to the software development effort must not be interpreted as a licensing of patent rights. The work of the JCT-VC is subject to the ITU-T/ITU-R/ISO/IEC Common Patent Policy, and patent licensing negotiations are to be conducted outside of the ITU-T, ITU-R, ISO, and IEC. Another concern of contributors is that the act of contributing to the software development effort also must not be interpreted as assuming some sort of liability of warrantee – the software is intended to be provided "as is".

- From the perspective of both the contributors and others that wish to use the software (e.g., for the development of products or for research or testing or the development of proposals), the primary concern is to ensure that there are no substantial copyright restrictions on how the software can be used. In particular, there has been no substantial desire expressed (among those consulted) to restrict the use of the software to conforming implementations of the resulting standard. Such restrictions could make users (and potential contributors) fear to obtain a copy of the software or use it as the basis of products for fear of potential liabilities that could arise from eventual (possibly inadvertent) adaptation of the software in ways that could drift outside of the scope of such a restricted field of use. Again, the intent seems to be to basically just provide the software "as is" without any substantial restrictions – other than potential patent rights as noted above.

- The software needs to be acceptable under the higher-level policies that apply to the parent bodies. Some further consultation within the higher levels of the parent bodies may be needed.

No other concerns have been expressed thus far among those consulted. Of course, it must be acknowledged that the JCT-VC (including its management) is a working group of technical experts who do not claim to have legal expertise.

One particular approach that may be a good one is to use the MXM form of the BSD license, which has been approved by the WG11 parent body at the 89th WG11 meeting, in the July 2009 output document N10791.

All of those involved in the software development effort thus far, with one exception, had agreed to allowing the software to be released under the BSD license. The hesitation expressed in the one instance

was not any disagreement in spirit, but only a desire to ensure that no patent rights are granted by the release of the software under this license.

If the MXM form of the BSD license as described is not adopted, alternative language would need to be established. Some efforts toward drafting such a candidate hypothetical alternative language had begun, but did not yet appear to be fully mature for consideration.

In regard to the software copyright issue, the following conclusions were suggested, and were supported by the JCT-VC as a whole:

- 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 in 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.
- In the event that we do not 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).

The JCT-VC work was reported to be moving forward well, and a substantial number of contributions had been submitted for review at the Geneva meeting.

In discussions of this report, it was suggested and agreed to plan for the reference software distribution package not to include binary executables.

JCTVC-B002 [K. McCann, M. Karczewicz, J. Ridge, S. Sekiguchi, T. Wiegand (chairs)] AHG report: Test Model under Consideration (TMuC) editing

This document summarised the activities of the ad hoc group on Editing the Test Model under Consideration (TMuC) document between the 1st JCT-VC meeting in Dresden, Germany (15 to 23 April, 2010) and the 2nd JCT-VC meeting in Geneva, Switzerland (21 to 28 July, 2010).

During the presentation of the report, the following issues were raised and discussed:

- The latest draft (rev 7) of the TMuC document was only made available shortly before the meeting. However, considering the amount of work it seemed impossible to meet an earlier schedule. Previous versions had been available for a sufficiently long time.
- Existing NAL and high-level syntax concepts of AVC should be re-used to the degree possible. For this purpose, a breakout group (led by Rickard Sjoberg) was established during the current meeting to identify which parts of AVC HL syntax are relevant, as further discussed below in the section relating to the break-out report JCTVC-B121. The operating assumption is that except as otherwise decided, we inherit the AVC High Profile design characteristics with frame_mbs_only_flag = 1.
- The TMuC documentation should also include an encoder description (which may be in a separate document from the syntax and decoding process). A plan was established at the current meeting to develop such documentation.

JCTVC-B003 [F. Bossen, P. Chen, D. Flynn, H. Schwarz, K. Ugur (chairs)] AHG report: Software development and TMuC software technical evaluation

This document reported the activities of the ad hoc group on TMuC software development. Substantial progress had been achieved with respect to the defined mandates: a common base software was identified and further developed according to defined priorities. The software was made available to JCT-VC members through public SVN repositories and limited experiments were conducted with it. This report further set forth recommendations to the JCT-VC for future software development activities.

During the presentation of the report, the following issues were raised and discussed:

- Some tools described in the TMuC document had not been not fully integrated yet.
- Tools that were classified as "lower priority" at the last meeting had not been not integrated yet.
- C versus C++: The majority of experts were asserted to prefer C code or C++ in C style (i.e., restricted use of C++ features).
- The software documentation must be significantly improved.
- The tools that are integrated are generally not well tested yet.
- It will be necessary to establish coding guidelines.
- TMuC text & software are lacking alignment in various respects. It was suggested that “software should take the lead” in the current situation. However, no conclusion on this was reached (except that it is necessary to check everything carefully).
- Software copyright issues need further clarification with the parent bodies.

JCTVC-B004 [C. Auyeung, S. Lei, K. Sugimoto, H. Yu (chairs)] AHG report: Intra prediction

This document summarized the Intra Prediction ad hoc grouip activities between the 1st JCT-VC meeting in Dresden, Germany (15 to 23 April, 2010) and the current 2nd JCT-VC meeting in Geneva, Switzerland (21 to 28 July, 2010).

During the presentation of the report, the following issues were raised and discussed:

- Experiments were performed using intra only coding, with loop filtering switched off
- AVC intra prediction was used as a basis to compare against.
- There is substantial relation between intra transforms and intra prediction, and potentially the loop filter. This must be taken into account in further investigation of intra coding tools.
- Although current activities of the AHG were performed under software platform KTA, it was targeted to switch to TMuC software after the meeting.

JCTVC-B005 [R. Cohen, R. Joshi (chairs)] AHG report: Alternative transforms

This document provided a summary of the activities carried out by the ad hoc group on Alternative Transforms between the 1st JCT-VC meeting in Dresden, Germany (15 to 23 April, 2010) and the 2nd JCT-VC meeting in Geneva, Switzerland (21 to 28 July, 2010).

During the presentation of the report, the following issues were raised and discussed:

- Although current activities of the AHG were performed under the KTA software platform, it is targeted to switch to the TMuC software codebase after the meeting
- Input contributions were mainly for intra (except JCTVC-B092 which handles both).
- Experimental configurations should be Intra-only or hierarchical B (for cases of transforms for intra-only and intra+inter).

JCTVC-B006 [B. Jeon, X. Wang, S. Wittmann, T. Suzuki (chairs)] AHG report: MV precision

This document provided a summary of the activities carried out by the ad hoc group on MV precision between the 1st JCT-VC meeting in Dresden, Germany (15 to 23 April, 2010) and the 2nd JCT-VC meeting in Geneva, Switzerland (21 to 28 July, 2010).

Excel sheets were provided specifying characteristics that were investigated.

During the presentation of the report, the following issues were raised and discussed:

- The AHG activities are related to MV precision and interpolation, which can be difficult to separate from other coding tools in terms of identifying the source of performance gains.
- The same is also true in relation with in-loop filters.

JCTVC-B007 [T. Yamakage, Y. J. Chiu, M. Narroschke, X. Wang (chairs)] AHG report: In-loop filtering

This document summarized the In-loop Filtering ad hoc group activities between the 1st JCT-VC meeting in Dresden, Germany (15 to 23 April, 2010) and the 2nd JCT-VC meeting in Geneva, Switzerland (21 to 28 July, 2010).

Several types of in-loop filters were investigated: Wiener-based, De-blocking/de-banding, Nonlinear (e.g. codeword restriction).

During the presentation of the report, the following issues were raised and discussed:

- In-loop filtering also needs investigation of subjective quality – how to arrange this?
- Levels of complexity of the different methods are quite diverse.
- It is necessary to combine this with an investigation of the TMuC design overall.

JCTVC-B008 [K. Panusopone, M. Budagavi, D. He (chairs)] AHG report: Large block structures

This document summarized the Large Block Structures ad hoc group activities between the 1st JCT-VC meeting in Dresden, Germany (15 to 23 April, 2010) and the 2nd JCT-VC meeting in Geneva, Switzerland (21 to 28 July, 2010).

The methods can be classified as "extended macroblock schemes" and "flexible quadtree schemes".

During the discussion, several participants raise their opinion that large structures could have impact on implementation complexity

JCTVC-B009 [M. Budagavi, A. Segall (chairs)] AHG report: Parallel entropy coding

This document summarized the Parallel Entropy Coding ad hoc group activities between the 1st JCT-VC meeting in Dresden, Germany (15 to 23 April, 2010) and the 2nd JCT-VC meeting in Geneva, Switzerland (21 to 28 July, 2010).

The different approaches can be categorized as bin-level, syntax-element level & slice-level parallelism. It is not fully clear whether each of these fulfils the same purpose or if coexistence is useful.

3 Summary reports of tool experiment (TE) status

JCTVC-B029 [M. Wien (RWTH Aachen Univ.), Y.-J. Chiu (Intel)] Summary Report for TE1 on DMVD

This document summarized the activities in Tool Experiment (TE1) on Decoder-side Motion Vector Derivation (DMVD).

A group of 15 companies had registered for participation in TE1. Between the meetings, a lively discussion took place on the JCT-VC email reflector, involving about 30 individuals representing the participating companies.

It was suggested to work within TMuC software context following the current meeting (rather than the KTA software context used up to the current meeting). Possibly, decoder-side derivation of other aspects (other than MVD) should be considered in future work.

JCTVC-B046 [T. Chujoh (Toshiba)] Summary of TE2 on IBDI and memory compression

This contribution was a summary of tool experiment 2: IBDI and memory compression. Nine companies and one university had been registered in TE2 and four proposed tools had been evaluated on the common conditions with cross-verification. There were 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. Detailed results were to be reported by proponents.

It was reported that in the case of memory compression (i.e. use bit-depth increase only for processing, but store as 8-bit) the bit rate increase is typically effected as 0.5-1%. Investigations had mainly been done with KTA software

The question was asked whether we might expect very different results from different software basis environments (except perhaps complexity)? There seemed to be differing opinions on that topic.

JCTVC-B053 [A. Krutz, T. Sikora (Tech. Univ. Berlin)] Summary report for TE3 on inter prediction in HEVC

This document summarized the activity of TE3. TE3 included activities on two subtests. Subtest 1 investigated parametric motion compensation. Subtest 2 is about flexible motion partitioning. For subtest1, two participants (LG, TUB) had conducted experiments and reported a significant improvement from these tools. Additionally, one related document from NCTU presented new results on MB Mode with joint application of template and block motion compensations. Three participants of subtest 2 (Technicolor, Huawei, Qualcomm) had contributed experimental results and reported further improvement of coding efficiency and computational cost on flexible motion partitioning. Overall the TE3 activity had made a significant progress regarding the proposed technologies.

It was remarked that parametric MC appears not to give significant gain for the CfP set, but reportedly does for some additional sequences selected by contributors.

Summary of status for TE4 on variable length coding

For TE4 (variable-length coding), no summary report was provided. These experiments did not show much activity. It was argued that the original planned test conditions were hard to pursue when considering the state of development of the TMuC software.

In this context, it was mentioned that in principle the original TENTM (JCTVC-A119) approach (grouping syntax elements together) can also be applied in the TMuC context, but this would take more time for integration before it can be properly tested.

4 TMuC analysis and Test Model development

JCTVC-B054 [M. Zhou (TI)] Proposed low complexity video encoder settings for HEVC

In recent years camera phones, camcorders, video surveillance and video conferencing applications have grown quickly and evolved into another major video market. Real-time, high quality video encoder and decoder at low-cost and low power consumption are required to serve this market's needs. In this contribution low complexity video encoder settings were proposed. By considering characteristics of the low-complexity encoder designs and projected circuit design capability, it was proposed to limit the maximum CU size to 64 x 64 and maximum transform size to 32 x 32, enable CABAC, IBDI and

simplified RDO, and turn off RDOQ and ALF in the settings. It was advocated that the HEVC tools should be tested for both high complexity and low complexity encoder environments so that the final HEVC design can satisfy the requirements of a wide range of video applications.

Some main differences of the suggested configuration vs. current plans were as follows:

- Minimum PU size 8x8
- Maximum transform size 32x32
- IBDI on (no strong opinion)
- Entropy coding not VLC

It was agreed to explore the potential benefit of 64x64 vs 32x32 maximum transform size in a TE.

JCTVC-B065 [T. Murakami, K. Sugimoto, S. Sekiguchi, S. Yamagishi, Y. Kato, K. Asai (Mitsubishi)] Consideration on guideline of complexity/performance balance for HEVC test model definition

This contribution provided information on guideline of the balance between computational complexity and coding performance to be considered toward HEVC test model definition. At the last Dresden meeting, the group made successful progress such that a recommended toolset "TMuC" as the starting point for defining a test model was created. To clarify the process of test model definition from the manufacturer's viewpoint, this document discussed two topics to suggest how to proceed for test model definition from the TMuC, 1) performance/complexity trade-off of the CfP submissions made at Dresden meeting, and 2) tool based evaluation using software of some best performing proposals that have been made available to the group so far.

Analysis of RD performance of proposals to CfP, and also encoding time compared to anchor (though having 20% and more benefit in terms of bitrate reduction, most proposals have more than 5x encoding time in their respective SW implementation compared to AVC anchors).

There was some concern expressed whether the figure is really precise.

Suitable performance/complexity tradeoff? Analysis of "complexity graph" from MPEG-1, MPEG-2, MPEG-4 and AVC show that most proposals are too complex to fall into this development.

Analysis on tools basis: Largest gains achieved by large blocks, large transforms and in-loop Wiener filter. These results were achieved by turning on individual tools (alternative could have been to turn on everything and turn off individual tools with all others running).

Definition of test model should be made based on tools that give comparably large benefits in compression against reasonable complexity.

Decoding time was not considered.

JCTVC-B087 [J. Lou, P. Krit, L. Wang (Motorola)] Performance Evaluation of TMuC

Test Model under Consideration (TMuC) has been being constructed since JCT-VC Dresden meeting. This suggested Test Model is intended to provide a coding efficiency close to the *best performing* proposals in the subjective test of the CfP submissions and also to provide a complexity point that is close to that of the *lowest complexity* submissions shown to provide substantial improvement of coding efficiency [1]. So far, four sub-versions are available at the SVN server, named as TMuC0.1 (modified from stripped JCTVC-A124 software), TMuC02 (with HHI's tools added), TMuC0.3 (with Tandberg's tools added), and TMuC0.4 (with Qualcomm's tools added).

This document presents the experimental results conducted on TMuC0.1, TMuC0.2, and TMuC0.3 in order for JCTVC to evaluate the performance of different TMuC sub-versions with different tools. For comparison, experimental results from JM16.2 with the same encoder parameter settings are used as the bench mark for comparison. BD-values of PSNR gain and bit-rate savings over JM16.2 were calculated. The detailed results could be found from the attached Excel file. Please note that the coding performance

difference between different TMuC sub-versions could not be simply subtracting one BD-value from another one.

Concerns that were raised about the reported results:

- Investigation based on all 18 sequences from CfP, but first 30 frames only for each
- Only High QP range considered
- Results on disabling large block sizes (drop of performance by 30% when switching off) could be questionable, as other participants report about different experience
- IBDI results (loss of 0.5% when switched off) could be questionable as well

JCTVC-B116 [M. Karczewicz, R. Panchal, P. Chen (Qualcomm)] TMuC performance evaluation

This contribution focuses on coding efficiency evaluation of TMuC 0.4. The average improvement of TMuC 0.4 over TMuC 0.1 obtained using the best combination of tools is 7.1% for the IPPP configuration.

Note: 2.5% out of the gain is caused by switching off early termination of the skip mode decision.

It was remarked that in general the RD optimization of current TMuC combination certainly requires more study.

Currently no investigation of the TMuC exists on a tool by tool basis.

Qualcomm indicated that they could provide their detailed results (including some tool by tool analysis) as a late contribution. An update of the software AHG report included results for both IPPP and hierarchical B cases.

JCTVC-B101 [G. Clare, J. Jung, S. Pateux (Orange Labs)] Preliminary results on motion vector prediction

This contribution provided some preliminary results on motion vector prediction in the TMuC. It is suggested to launch a Tool Experiment on the subject.

Comparison of interleaved MV prediction and MV competition was performed. It is reported that MV competition alone has highest performance (approx. 1.3% better than combination with IMVP).

JCTVC-B120 [F. Bossen (BoG)] Report of TMuC design BoG

A break-out session was held on July 22 from 2pm to 5pm in room T103 to discuss future TMuC software development and testing. Notes taken during the meeting were included in this document.

Settings were agreed as in that document (including the selection of InterpFilterType = 4 for the high-coding efficiency configuration), relative to JCTVC-B003 configurations, with additional notes as follows:

Three coding structures are planned to be used in experiments:

- IBBB (without frame re-ordering and without hierarchical QP assignment among B frames)
- Hierarchical B (as in Alpha CfP anchor) with length-8 structure (using forward-predictive B frames rather than P frames)
- All-intra

Each of these has *two* complexity-level configurations, i.e. 6 configurations in total.

The configuration files were made available by Monday noon on the reflector. Hierarchical coding should be set to 0 for low delay, and NRF should be set to 0 for the low delay case.

It was decided to issue the agreed configurations as JCTVC-B300.

Experiments for intra may only use all-intra coding. Experiments for inter techniques may omit the all-intra case, but should include both of the other coding structures.

Test sequences to be used – as in the CfP.

Number of frames to be encoded: full length as used in CfP.

This also applies for cross-checking – in this context it was emphasized again that cross-checking is a serious task including more than just running software. Particularly, cross-checkers shall inspect the source code and be able to understand the implementation.

New planned integrations - agreed:

- Modification of MV prediction in JCTVC-B094 (config issue)
- Harmonization of intra prediction modes per JCTVC-B100
- Rounding-related proposal JCTVC-B074 (B frame rounding control, for which verification was reported in JCTVC-B046, and more transform LSBs)

Plans for TMuC software development:

By the end of this meeting – some bug fixes and VLC integration should be ready for release. Within 7-10 days after, can include intra harmonization per JCTVC-B100, edge-based intra prediction, motion vector scaling, and block merging – and hopefully JCTVC-B074. Somewhat later, adaptive loop filter refinement integration is planned (not affecting the default behavior).

Experiments should use the best software that is available by 9 August or some later more-improved version – both for experiments on evaluation of tools already in the TMuC and additional proposed aspects.

Anchor data from that software will be made available (bitstreams, checksums, Excel spreadsheet) shortly after the corresponding version of the software is made available. This task is assigned to Software integration AHG, and BBC has volunteered to provide an ftp site.

Each proponent who performs an integration that materially affects the software beyond that version (other than fixing a clear error) needs to provide an analysis of the effect of that change.

It is desirable to measure TMuC progression beyond that version. In particular, the “low priority” tools have not been integrated in TMuC so far, but should be tested against the default under the same conditions. should be documented by reporting results as in a TE.

In principle, it is agreed that it should be possible to switch off any coding "tool", either in the config file or in TypeDef.h.

The following issues were raised during the discussion:

- Software copyright handling – noted as an issue, as further discussed in JCTVC-B001.
- How do we bring subjective quality more into our process?
- Improving encoder descriptions in the TMuC document.

The following additional information was brought during the discussion:

MDDT may need to be further optimized, possibly mapping needs to be changed when the harmonization of JCTVC-B100 is implemented.

Loop filter (ALF) modifications are expected to take somewhat longer (2weeks+). Major modifications to VLC encoder (including operational version of RDOQ) most probably only by end of August.

Another discussion was conducted Monday 14:00 on default config files for which a draft was previously submitted via the reflector.

The usage of only B frames for inter-predictive coding was confirmed both for the random access (in that case, forward predictive B rather than P) and low delay cases.

One issue discussed was the potential usage of only one reference frame for L0 and L1 – each would be better in coding efficiency as it would avoid potentially unnecessary encoding of refidx; this would however disable opportunities of multi-hypothesis prediction (B prediction from 2 areas of same frame).

It was suggested that the rate variation measure (RVM) that was used in the CfP testing should be implemented in the software.

It was reconfirmed that interpolation filter type 4 is used for the high complexity case as discussed on Friday.

Currently only one case is known where a tool cannot be switched on and off. The goal is to have all tools switchable (either as config file option or in typedef as compile option).

NRF=1 and hierarchical coding should be set to zero for low-delay case.

JCTVC-B121 [R. Sjöberg (BoG)] Report of High-level syntax BoG

A break-out session was held on July 24 from 11:30 a.m. to 2:00 p.m. in room A to discuss what high-level elements to carry over from AVC to TMuC as a starting point.

A report of this break-out activity was presented and agreed as supported by the group. The planned high-level syntax is based on the AVC high-level syntax but is stripped of elements that are not needed or not appropriate in TMuC.

Questions raised included whether support for interlaced-scan video coding features and color formats other than 4:2:0 was needed in the high-level syntax.

It was emphasized again that no requirement for efficient coding of interlaced-scan video exists in the requirements documents of the parent bodies. Other color formats such as 4:4:4 will need to be developed, but this requires changes to the software at various levels, and is not currently of high priority.

Most of the HL syntax definitions suggested by the BoG would currently only be included in the text document, not implemented in software.

JCTVC-B122 [W. Wan (Broadcom), P. Topiwala (FastVdo), P. Pandit (Harmonic), H. Yu (Huawei), Y. Chiu (Intel), B. Jeon (LG), S. Lei (Mediatek), S. Sekiguchi (Mitsubishi), K. Panusopone (Motorola), K. Chono (NEC), Y. Shishikui (NHK), A. Segall (Sharp), M. Zhou (TI), T. Chujoh (Toshiba), T. Suzuki (Sony)] Proposed approach on test model development (late)

This document was submitted late, on Monday 26 July.

This document proposed an approach for the development of the HEVC Test Model (TM). The stated goal was to accelerate the process of evaluating and developing the HEVC standard in a constructive way. As a first step, it was proposed to define a "reference configuration" of the TMuC software by the conclusion of the Geneva meeting. This "reference configuration" would include only one tool for each, significant functionality. As a second step, it was proposed to evaluate additional tools by comparison with this "reference configuration". The stated goal was to simplify the implementation of remaining tools, as well as other tools, into common software for evaluation. Finally, it was proposed to put more focus on the encoder description during the editing of the TMuC document, with the goal of ensuring a fair evaluation of coding tools.

Issues that were stated:

- Define reference configuration: During the presentation, the authors largely agrees with discussion on Sunday. Request that an output document is provided along with the config files that textually describes the tools in default config. Possibly also a kind of software manual.

- Define procedure for TM definition based on evaluation of single tools (note: actually, this is the purpose of TE12)
- Develop encoder description (note: Will this be the same document? Who is responsible – same group of people that edits the TMuC?)
- Request to have anchor data within one month after the meeting. Potentially, to achieve this, each TE could contribute part of the resources.

Much of the content of the contribution seemed to essentially be suggesting plans that had already been agreed or assumed. However, discussing the subjects again explicitly was useful.

It was requested to produce a document describing which tools are used by the reference configuration.

In discussion of the contribution, it was suggested that there should be a document (perhaps the same document) describing how to enable/disable each tool, and where any conflicts might arise in their use in combination.

For adoption into the test model, a proponent must provide adequate evidence of intended benefit based on appropriate metrics, including tool-by-tool analysis and consideration of interaction with other tools – and the effectiveness needs to be verified by a 3rd party. It was agreed that this is our planned (and usual) way of operating.

In terms of evaluation needs, there should not be any presumption of a difference in status between tools in the reference configuration and other tools.

It was requested that an encoder description should be provided for the TMuC tools. It was agreed to create such a document – as a separate document from the decoder description. The creation of this document as JCTVC-B204 was assigned to the TMuC editing AHG.

It was requested for there to be a "reference configuration" of the TMuC software. This had already been planned.

In regard to the evaluation of tools that are already in the TMuC, the inclusion of something in the "reference configuration" setting should *not* be construed as a selection of technology that needs less analysis and justification than any other feature. This was agreed.

It was suggested to test the effectiveness of transform blocks (TU) that span across multiple prediction unit (PU) blocks. This may be necessary for some asymmetric PU partitioning schemes, but may not be desirable for ordinary 2^nx2^m rectangular partitioning (assuming the segmentation signaling is designed appropriately).

It seems that currently only one tool (asymmetric partitioning) cannot be switched off.

JCTVC-B122 requested using only one default configuration setting (instead of high and low complex modes)

- usage of AVC intra coding modes for 4x4 and 8x8
- usage of up to 32x32 transform only
- usage of 12-tap DCT-based interpolation filter
- usage of PIPE
- usage of IBDI
- switch off combined intra prediction
- switch off merge mode
- switch off rotational transform
- switch off adaptive intra smoothing

After discussion, it was agreed to use the reference configurations described elsewhere in this report as documented in JCTVC-B300.

JCTVC-B123 [F. Bossen (BoG)] BoG report on TMuC software configuration

Another breakout group was held on Monday 7/26 from 3-4pm in Room C. Participants included a majority of JCT-VC participants.

The purpose of break-out was to identify differences between software configurations discussed so far in the JCT-VC meeting and those proposed in JCTVC-B122.

The BoG reviewed appendix 6 of JCTVC-B122, including tool table and software encoder configuration file.

Several questions were raised about the current state of intra prediction (number of modes, etc). The configuration proposed in JCTVC-B122 seems not to be supported by the TMuC software (e.g., 9 AVC modes for 4x4 (defined in JCTVC-A205) and 8x8 (not defined in JCTVC-A205)).

Plan for Test Model development

Our plan is to establish a "Test Model 1.0" in October.

The "Test Model" will contain only the minimum set of well-tested tools that together form a coherent design that is confirmed to show good capability. The "minimum set" may include such variations as would be appropriate for forming multiple profiles of the design.

What we have now is a "TMuC". The concept of the TMuC may still exist after October.

The TMuC is a "rough best guess" of a set of tools that has appeared to show promise.

The TMuC may contain some duplications/overlaps/variations of functionality that we would not accept in the confirmed Test Model.

Our current TEs are planned to be performed relative to "reference configurations" of the TMuC selected for the set of sequences in the CfP test set with the planned QP set (see JCTVC-B120 and this report).

In regard to the evaluation of tools that are already in the TMuC, the inclusion of something in the "reference configuration" setting should not be construed as a selection of technology that needs less analysis and justification than any other feature.
In principle, it is agreed that it should be possible to switch off any coding "tool" that is in the TMuC, either in the config file or in TypeDef.h.

5 Contributions on specific technical features

5.1 Parallel entropy coding

JCTVC-B034 [G. Korodi, D. He (RIM)] Source selection for V2V entropy coding in HEVC

A class of binary entropy coders processes the input sequence by encoding each binary symbol with a known probability from a discrete, finite set. The compression efficiency of such a system is affected by the magnitude of the set, and the accuracy by which its values approximate the empirical probabilities. This contribution provides a method for dynamically mapping the probability set to one of its subsets, with the objective of increasing compression efficiency. By coupling this method with parallel V2V coding, it becomes possible to achieve the desired throughput while at the same time provide competitive compression efficiency against CABAC as specified in ITU T Rec. H.264 | ISO/IEC 14496-10.

"Dynamic source selection" tries to model the probability distribution of a binary source better than the usual empirical approaches. Basic idea is partitioning of encoder states, where the best partition is selected to best match the source statistics.

Dynamic mapping is an iterative approach for determination of best state partition and corresponding code tree.

Best partition is encoded for each slice (40 bits per slice). Finding that for cases where the number of bits becomes large (>500000) the adaptive code can have slight reduction of bits compared to CABAC.

CABAC is used to estimate the probabilities. In principle this is a two-pass encoding method with side information. The multipass requirement for processing in the scheme was noted.

It was asked how much gain was produced for having the adaptive selection.

It was noted that CABAC has 2-bit context initialization (cabac_init_idc).

CABAC could also be initialised by such a an approach, potentially the advantage would disappear.

It was remarked that although the V2V schemes may address issues in the core of the binary coding, we still have a bottleneck in the binarization and context model aspects.

It was suggested to establish a related TE (RIM, TI, LG expressed interest)

JCTVC-B036 [D. He, G. Korodi, G. Martin-Cocher (RIM)] Improved parallelism for V2V entropy coding in HEVC

The V2V coding method described in the Test Model under Consideration for HEVC provides potentially significant throughput improvement over CABAC in ITU-T Rec. H.264 | ISO/IEC 14496-10. It is however observed that the context modeling process might become the bottleneck limiting the throughput of the whole decoding process. In order to improve throughput of coding residual data, a coding order that groups significant_coeff_flags and last_significant_coeff_flags according to their contexts is described. For these syntax elements, this coding order allows multiple bins to be processed in a single table lookup, whereas such table lookups are impractical with the existing coding order defined in ITU-T Rec. H.264 | ISO/IEC 14496-10.

Some coding efficiency impact – typically 0.5% or less.

A problem is that context modeling becomes the bottleneck (as it works serially).

Approach 1: For transform blocks: Use table lookup to determine the states for multiple bins simultaneously. In case of 4x4 blocks, this leads to minor increase in bit rate (larger blocks are somewhat more penalized, due to the fact that the number of possible states increases and needs to be limited in the table)

Approach 2: Idea to change the frequency in updating the states in context modelling (e.g. when update is performed at each 4th bin, 4 bins can be processed in parallel). This leads to a performance drop of 0.5 and 0.7 % for RaceHorses and BQMall, respectively. In fact, the assumption of 4x throughput in this case seems to be an upper limit.

JCTVC-B088 [M. Budagavi, M. U. Demircin (TI)] Parallel context processing techniques for high coding efficiency entropy coding in HEVC

Context-Adaptive Binary Arithmetic Coding (CABAC) is one of two entropy engines used by the AVC video coding standard. Processing in 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. Several techniques to parallelize CABAC were proposed in different contributions in response to CfP at the last JCT-VC meeting. The parallelism proposed in those contributions can be broadly classified into three categories: bin-level parallelism, syntax element-level parallelism, and slice-level parallelism. The 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. Hence techniques that parallelize context processing and binarization are required. This contribution presents the following three different techniques for parallelization of context processing (PCP) for improving throughput of the whole entropy coder: Coefficient Sign PCP,

Coeff Level BinIdx 0 PCP, significance map PCP. In addition, this contribution also explains the advantages of syntax element partitioning from perspective of parallelization of binarizer and context processing.

Syntax element parallelism.

Three parallel context processing techniques: coefficient sign, coefficient level bin index 0, and significance map.

Binarizer and context modeller need to be parallelized. Possibilities: A) Syntax element partitioning. B) Parallel context processing, e.g. significance, sign, level of coeffs in case binidx=0. Sign to be sent in a separate plane.Significance map: Significant coeff flag and last coef flag: If last cannot be sent at any place, throughput is increased, but slight increase in bit rate due to necessity to send more significant coeff flags.

JCTVC-B111 [K. Misra, J. Zhao, A. Segall (Sharp Labs)] Entropy slices for parallel entropy coding

The concept of an Entropy Slice was proposed for the HEVC system. Entropy slices enable separate entropy coding neighborhoods in the entropy decoding and reconstruction loops. Motivations for entropy slices were suggested as follows:

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 accommodates 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 bit-stream 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 for entropy coding. Specifically, profiles/levels may define bin limits per entropy slice, as opposed to imposing such limits for an entire picture. This was asserted to be useful for all applications, but with an especially significant benefit to emerging higher rate and higher resolution scenarios.

A participant commented that needing to obey a bin limit on an entropy slice might be a burden on encoder designs, and suggested that such a limit should perhaps be imposed that does not include the last macroblock of the slice.

The proponent emphasized that the header size for the proposed entropy slice design is small.

The need to buffer the decoded symbols in the decoder was also mentioned as an implementation issue.

No particular further experiment appears to be needed on this topic, at least at this time.

The basic concept of desiring enhanced high-level parallelism of the entropy coding stage to be in the HEVC design is agreed.

It was remarked that interleaved entropy slices (JCTVC-A101) is a somewhat competing concept.

Plan to establish an AHG on parallel entropy coding. The AHG should study the merits of these approaches (and potentially others if such can be identified). The study does not necessarily need to be in the TMuC context, although that would be preferred.

Entropy slice contains a definable maximum number of bins for which the decoding is independent of other entropy slices (unlike usual slices which have variable number of bins). Signaled in the slice header by entropy slice flag plus information that is necessary to initialize the entropy decoder.

Output of the parallel entropy decoders needs to be buffered to allow further parallel processing.

Questions are raised whether this also allows parallel processing at the encoder.

Experimental results (using 32 entropy slices on a 1080p picture which are processed by 4 parallel decoders) show that the effect on coding efficiency is low (<0.1%) for the tested configurations.

Conclusion: Basic concept of including parallelism at high level is agreed; establish AHG to elaborate concepts to include such a concept in the TMuC (there is also JCTVC-A101 that proposed a similar concept). If experimentation is necessary, it would

5.2 Large block structures

JCTVC-B028 [M. Zhou (TI)] Coding efficiency test on large block size transforms in HEVC

Large block size transforms are a new coding tool proposed to the HEVC for improving coding efficiency. In this contribution, the coding efficiency test results of the large block size transforms are presented. Testing results showed that the large size transforms (32x32 and 64x64) provide an average gain around 1 ~ 2%; the large size transforms are most effective in 1080p (Class B) sequences in which an average gain of 3% (peak gain 6 ~ 9 %) is observed; the additional gain by adding 64x64 transform on the top of 32x32 transform is very limited.

The software that was used was the distributed "stripped version" of the JCTVC-A124 software. For each sequence, 121 frames were coded. It was remarked that coding longer sequences might help.

More detailed summary of the report given: Disabling 64x64 transform leads to a bitrate increase of 0.2% on average, disabling both 64x64 and 32x32 transform leads to an increase of 1.34% on average for hier. B; likewise for IPPP 0.40/1.89; for intra only 0.1-0.2/1.1-1.3. Typically higher gain for class B; Kimono gives largest gain, 9% reduction by using 64x64 maximum compared to 16x16

It was remarked that it may be helpful to measure statistics about how often the transforms are used, broken down according to video resolution classes.

It was also remarked that subjective quality effects should also be studied – in this respect the large block sizes may be more helpful.

Investigation on benefit of large block sizes should be conducted; this should also include a study about the benefit for the various resolutions (i.e. make the usage dependent on the picture size); subjective factors should also be included.

JCTVC-B050 [B. Lee, M. Kim (KAIST), H. Y. Kim, J. Kim, J. S. Choi (ETRI)] Hierarchical variable block transform

In this contribution, a rate-distortion optimized variable block transform coding scheme was proposed based on hierarchical variable-sized block transforms for macroblock (MB) coding with a the order-4 and -8 integer cosine transform (ICT) kernels of H.264 | MPEG-4 Part 10 AVC in addition to a new proposed order-16 ICT kernel. The set of order-4, -8 and -16 ICT kernels were applied for inter-predictive coding in square (4×4, 8×8 or 16×16) and two non-square (16×8 or 8×16) transform cases for each MB in a hierarchically structured manner. The proposal was tested in the KTA software context. The proposed hierarchical variable-sized block transform scheme using the order-16 ICT kernel reportedly achieves average 3.8% bitrate reduction for test sequences of Constraint Set 2 (low delay), compared to the High profile of H.264 | MPEG-4 Part 10 AVC and reportedly shows a promising possibility of further developments in conjunction with enlarged MBs in the future Test Model of HEVC.

Performance of the additional transforms seems best in high bit rate range (since this is where the transform is used more and fewer coding blocks are skipped) and when non-AVC KTA tools were disabled (since these reduce the amount of residual needing to be coded with the transform). Adding an order-32 case was asserted to potentially improve performance further.

It was remarked that some of the added block sizes might not get used very much if 32x32 is also available, and that if an encoder needs to consider their use, this would be an added processing burden for encoders.

It was also remarked that requiring a decoder to support more transforms imposes an added burden on decoder implementation.

Further study was encouraged.

JCTVC-B082 [K. Sato (Sony)] New large block structure with reduced complexity

The AVC standard employs the concept of macroblocks that consist of 16x16 luma samples and typically 8x8 chroma samples, and most proposals of the response to CfP extended the macroblock (maximum coding tree block) size to 64x64 or 32x32, which was reportedly one of the key tools of coding efficiency improvement.

However increasing the macroblock size reportedly has two problems in terms of implementation: First, it causes an increase in buffering to store samples from the neighboring macroblocks for intra prediction or deblocking filter application. Second, the order of processing for each of 16x16 blocks differs from MPEG-2 or AVC if larger macroblock than 16x16 is employed. This would reportedly become a bottleneck in developing multi-codec LSI chips.

This contribution proposed using a non-square scheme such as 32x16 or 64x32, which would reportedly provide a trade-off solution between coding efficiency and complexity or compatibility with existing codec designs.

The reported simulation results (based on KTA2.6r1) compared the average gain obtained with 32x32 and 32x16, with the assertion that 91.4% of the gain was obtained for IPPP with lower QPs, 79.1% for IPPP with higher QPs, 83.1% for HierB with lower QPs, and 64.5% for HierB with higher QPs.

It was suggested that using a non-square coding block provides a good trade-off between coding efficiency and implementation cost or interoperability. It was proposed for this topic to be included in the discussion of AhG on Large block structures.

It was remarked that having an excessively large macroblock size could cause problems in relation to typical memory designs which have problems with units larger than 1024 bytes.

A participant indicated that it would be better (from the implementation perspective) to fix the maximum coding tree block (CTB) / macroblock size rather than requiring decoders to support raster scans of different block sizes.

It was remarked that some features of the TMuC, such as merge flags with 16x16 maximum CTB size, might enable some similar functionality in a different way – although another participant indicated that the current TMuC may not support the use of a merge flag across CTB boundaries.

During the discussion, voices are raised that between 32x16 and 32x32 there is no real difference in burden with regard to hardware implementation, but possibly for larger units such as 64x64 and 128x128.

One suggestion was given that the same could be done using the merge flag of TMuC (binding together two 16x16 CUs). This would however require that the merge flag can be applied at the top level (which is not the case currently)

Continued study (in TE or AHG activity) was encouraged.

5.3 TE2: IBDI and memory compression

JCTVC-B044 [T. Chujoh, T. Shiodera, T. Yamakage (Toshiba)] TE2: Adaptive scaling for bit depth compression on IBDI

In this contribution, detailed results of an adaptive scaling for bit depth compression on IBDI are reported. This is one of proposals in Tool Experiment 2 on IBDI and memory compression. The purposes of this tool experiment are to improve coding efficiency by increasing internal process of video codec while minimizing reference frame memory access bandwidth and to reduce reference frame memory access bandwidth and reference frame memory size. This contribution shows a solution of the first purpose and as experimental results, the loss bitrate is average of 0.13% for bit depth compression on IBDI.

Memory compression applied with IBDI on and off; loss compared to IBDI (12 bit mapped to 8 bit) is 0.13% in terms of bit rate. Adaptation to the dynamic range of each 4x4 block (offset + scale values are encoded additionally). Gives better result than fixed scaling. Requires computation of histogram as first step.

Coding: 1 bit signaling fixed (8 per sample) or adaptive scaling

(2 bits for scale, 8 bits for offset, 7 bits per sample = 122 instead 128)

A participant remarked that switching fixed/adaptive could cause problems in random access as necessary for MC.

It was suggested to investigate complexity compared to other methods.

JCTVC-B057 [H. Aoki, K. Chono, K. Senzaki, J. Tajime, Y. senda (NEC)] Performance report of DPCM-based memory compression on TE2

This contribution presents the 1-D DPCM-based memory compression method proposed in JCTVC-A302 for Tool Experiment 2 (TE2) and reports its performance. The proposed method is designed to reduce actual memory bandwidth with relatively low complexity, in particular, in motion compensation. Motion compensation frequently and randomly accesses to frame memory for reading reference pixels. In consideration of the tradeoff between memory accessibility and image quality, the proposed method employs simple 1-D DPCM. It has been tested with two constraint sets in two experimental conditions: one is 3/4 memory compression without IBDI and another is memory retainment even with 12-bit IBDI. Experimental results have shown that average coding losses are 7.757 % for CS1 without IBDI, 11.552 % for CS2 without IBDI, 0.573 % for CS1 with IBDI and 1.157 % for CS2 with IBDI, respectively. Subjective quality degradation caused by such coding loss is invisible for most test cases. Additional experimental results have also shown that memory compression only at the decoder side causes significant coding loss. It is therefore suggested that memory compression tool should be adopted as one of optional codec components so as to be available for memory-conscious hardware implementations, such as SoCs. As for memory accessibility, the impact on actual memory bandwidth has not yet been evaluated in TE2. Hence it is recommended that it is next studied in TE/CE on memory compression for Test Model.

Problem in MC: Memory access is not aligned; compression should not interfere with random access. Compression units should not be too large. This is the motivation to use 1D DPCM with non-uniform quantizer (based on LUT). Groups of 8 samples, in case of 12 bit IBDI 12 bit for first sample, 7 bits for subsequent samples. Visual degradation is reported for Vidyo3 (ringing artifacts, most probably due to quantizer overshoot at edges).

Loss in BR compared to IBDI around 1+%.

One additional Result for CS2 shows high increase of bitrate (60%). Actually, that variant of the scheme scheme was only applied at the decoder, such that drift occured. Such a configuration should not be used in general.

A participant remarked that in terms of memory access, a 2D compression unit of size 4x4 may be more advantageous than the suggested 1D DPCM.

JCTVC-B074 [M. Karczewicz, H.-C. Chuang, P. Chen, R. Joshi, W.-J. Chien (Qualcomm)] Rounding controls for bidirectional averaging

Two modifications for increasing the precision of bi-directional prediction and DCT transform, when IBDI mode is not used, were proposed. The average BD rate reduction is 2.58% for IPPP configuration and 1.36% for hierarchical-B configuration. The results are obtained using TMuC 0.2.

Experiment performed in TMuC. Rounding approach same as in VCEG-AI020 and implemented in KTA, signaling the rounding direction for the case of bi-prediction. Report that gain due to IBDI is higher in TMuC than in JM (around 3.5 % than 2%). Experimented with additional change in DCT where the

rounding in the fast algorithm is always going in one direction. If that is modified (similar to the 8 bit integer DCT in 23002-2), the gap between using IBDI and using it not becomes lower.

The contribution mentions a DCT rounding issue which is further discussed in the context of the TMuC environment.

JCTVC-B086 [S. Oh, S. Yea (LG)] TE2: Memory access bandwidth for inter prediction in HEVC

In this contribution an experimental result on memory bandwidth for HEVC is provided. With increasing popularity of high-definition or higher resolution materials for all types of video devices, consideration for memory access bandwidth issues is becoming ever more important. In this contribution, the number of pixels to be accessed from the frame buffer is used as a measure to estimate memory bandwidth of the decoder. It is observed that, under TE2 coding conditions using the class B sequence, the use of extended MB tool in KTA2.6r1 leads not only to the coding gain but also the reduction of memory bandwidth.

Analysis shows that overhead in memory access (e.g. due to additional pixels required for interpolation) is by tendency getting lower for larger blocks.

It was remarked that we should better understand whether this is still true when caching is used.

The contribution shows that memory accesses are saved when a larger portion of large MB's is used. It does not answer the question what losses occur and how many memory accesses are saved if small blocks would be restricted.

JCTVC-B089 [M. U. Demircin, M. Budagavi, M. Zhou, S. Dikbas (TI)] TE2: Compressed reference frame buffers (CRFB)

An in-loop memory access bandwidth reduction technique is proposed. Proposed tool compresses the reference pictures before they are written to the memory and decompresses before they are being read. Fixed compression ratio is targeted for a block of pixels to enable random access. Proposed technique provides 12 bit/pixel to 8 bit/pixel compression when Internal Bit-Depth Increase (IBDI) tool is turned on. 8 bit/pixel to 4 bit/pixel compression is achieved when IBDI is disabled. 2-D integer S-transform on 8x8 blocks, DC prediction, quantization and variable length entropy coding is employed. Performance is tested and verified as a part of the Tool Experiment 2 (TE2). Proposed algorithm results a worst case BD-Rate increase of 1.01% for Class A, B and E bitstreams for IBDI-on and 0.80% for IBDI-off settings.

Investigations: 12 to 8 bit compression for IBDI, 8 bit to 4 bit compression with non-IBDI. Requirement of random access makes this hard (requires small units and fixed length codes).

Algorithm uses transform, quantization, DC prediction (not in IBDI case), EG0 and EG3 entropy coding. Current loss is 0.16% for CS1 and 0.32% for CS2 in IBDI,

8x8 access units, Wavelet transform similar to Haar is used. Fixed number of bits is used per 8x8 block.

Issues raised: This could lead to the case where single blocks of high detailed blocks are looking highly distorted. Visual quality inspection should be made, both at low and even more high QP.

Same conditions should be used in any case. Study must be performed on statistical basis what an allowable / useful access unit size is, e.g. it could happen that 8x8 is too large when four blocks must be accessed to grab one block for MC in cases of heavy overlap. (e.g. assume certain statistical distribution of MC blocks and of MC access positions)

JCTVC-B103 [C. S. Lim, H. W. Sun, V. Wahadaniah (Panasonic Corp)] Reference frame compression using image coder

This contribution presents a reference frame compression scheme using an image coder. The presented image coder includes a transform, scanning and bitplane coding. Experiments were conducted by running the various software (TMuC revision 25, modified TMuC with 50% reference frame compression, modified TMuC with 33% reference frame compression and JM16.2) using the test set defined in JCTVC-A302 document.

In comparison with the TMuC software without reference frame compression, this document reports a drop of 1.41% in the average coding gain over JM16.2 for CS1 and a drop of 0.25% in the average coding gain over JM16.2 for CS2 using reference frame compression of 50%.

In comparison with the TMuC software without reference frame compression, this document reports a drop of 0.95% in the average coding gain over JM16.2 for CS1 and a drop of 0.14% in the average coding gain over JM16.2 for CS2 using reference frame compression of 67%. It can be noted from the results in both CS1 and CS2 that the largest drop in performance occurs in the smallest resolution images.

This proposal shows that image coder based approach can provide good compression efficiency for reference frame compression especially for the large resolution sequences and recommends JCT-VC to consider standardizing an image coder for reference frame compression.

Uses DCT, zigzag scan, bitplane coding, simple + entropy coding (similar to MPEG-4 FGS)

Results in IBDI case (12 bit) 1.41% BR loss for CS 1, 0.25% for CS2 in case of 50% compression (12-to-6) and 0.95% or 0.16% in case of 33% compression (12-to-8)

Note 1: the higher loss in CS1 is probably due to the required higher quality of I pictures.

Note 2: This algorithm is certainly significantly more complex than others presented so far.

JCTVC-B114 [Z. Ma, A. Segall (Sharp Labs)] System for graceful power degradation

The contribution proposes a system that enables the low resolution decoding of a bit-stream without drift. The system consists of a buffer compression algorithm that reduces memory bandwidth for all devices, and a low resolution decoding mode that enables optional, lower power operation. We assert that this lowest power mode is beneficial for battery powered devices and additionally benefits devices with screen resolutions lower than the content resolution. To achieve our goal, we propose to store sub-sampled and compressed versions of reconstructed frames in the decoded picture buffer. We then store prediction and residual data to reconstruct the missing pixels. The result is buffer compression. Additionally, we allow encoders to selectively disable the residual correction for the missing pixels data and transmit the prediction component explicitly. As will be described in the document, this leads to a low resolution decoding functionality.

The basic idea is to be able for decoding either a low or high resolution version of a sequence, switchable on frame by frame basis

Use quincunx sampling for a low-resolution picture and a high-resolution residual. Compressed from 12 to 8 bit; in case where the residual is close to zero, it can also be skipped.

MC is then only applied on low resolution pixels. Also combination possible, i.e. decoding of full resolution, but MC and frame buffering only with low resolution.

Quincunx subsampling is performed without filtering; this can cause aliasing, which is removed by post processing (not in the loop)

It was remarked that quincunx sampling could also potentially introduce color artifacts

Resolution reduction adds another degree of freedom in memory compression. If this would come for free, it would be fine, but needs to be investigated whether this is true (also visually) for various sequences.

JCTVC-B090 [M. Budagavi, M. U. Demircin (TI)] ALF memory compression and IBDI/ALF coding efficiency test results on TMuC-0.1

ALF estimation is a complex process that involves calculation of correlation coefficients for determining Wiener filter, selection of filter size (5x5, 7x7 or 9x9), and selection of frame blocks on which to apply the filter. The deblocked frame buffer is read multiple times in the ALF estimation process. For example, in existing TMuC-0.1, the deblocked frame buffer is read more than 10 times dramatically increasing the memory bandwidth required. Increased memory bandwidth leads to increased cost and increased power.

This contribution proposes the use of memory compression for ALF bandwidth reduction. Note that ALF memory compression is different from Tool Experiment 2 (TE2) IBDI and memory compression in the sense that ALF memory compression operates on deblocked filter output (which is ALF input) whereas TE2 techniques operate on ALF output (which is reference frame). Simulation results on TMuC-0.1 show that ALF memory compression from 12bits➔8bits achieves 33% memory bandwidth and memory size reduction at the cost of average BD-Rate increase of 0.22%. ALF memory compression from 12bits➔6bits achieves 50% memory bandwidth and memory size reduction at the cost of average BD-Rate increase of 0.32%.

This contribution also presents ALF and IBDI coding efficiency simulation test results on TMuC-0.1 when one tool is turned off at a time. When ALF is turned off, there is an average BD-Rate increase of 5.82% for ClassA&B sequences and 3.97% over all sequences. A noticeable data point is that maximum BD-Rate increase when ALF is turned off is 13.26%. When IBDI is turned off, there is an average BD-Rate increase of 3.88% for Class A&B sequences and 2.61% over all sequences.

Goal: reduce memory bandwidth mainly in the ALF estimation. Otherwise the algorithm is basically the same as in 089. Most probably, this could be seen as an encoder-only issue.

Additional result: average over all sequences 3.97% saving with ALF, 2.61% with IBDI.

Conclusions on IBDI & Memory Compression

It was agred to establish a TE on memory compression with additional emphasis on

- Sizes of access units (should be comparable, and idea about the overhead that comes due to overlaps in random access)
- In which parts of the codec is IBDI necessary – only for processing, or also for storage?
- Due to the need for fixed bit rate per acces unit, subjective impairments may appear locally -> subjective investigation needed.
- Complexity investigation of different methods
- Is built-in spatial scalability useful e.g. for power saving?

It was also recommended to establish an AHG to study these issues.

5.4 TE1: Decoder-side motion derivation

A summary report on this topic is found in JCTVC-B029.

JCTVC-B026 [S. Klomp, M. Munderloh, J. Ostermann (Leibniz Univ. Hannover)] Decoder-side motion estimation with modified reference list

This proposal relates to improving compression by performing additional motion estimation at the decoder. As only already decoded data is used, no additional data is transmitted.

This document gives an update of the results presented in Doc. M16570 on the performance of decoder-side motion estimation (DSME) with new test sequences. A dense motion vector field is estimated which reduces the rate by 6.9% in average compared to the H.264/AVC anchors at the same quality.

Used JM 16.2, with conventional MB size.

Remark: Is the dense motion vector field useful? To be studied – a matter of complexity.

JCTVC-B030 [M. Wien, S. Kamp (RWTH Aachen Univ.)] TE1: RWTH partner report on DMVD

In this contribution, an RWTH tool description and simulation results for the contribution to the Tool Experiment TE1 on Decoder Side Motion Vector Derivation (DMVD) were provided. The technical

description of the proposed tools in this document closely relates to the tool description provided as in the response to the Call for Proposals for HEVC.

Simulation results are provided relative to the defined TE1 simulation conditions. The accompanying spreadsheets provide rate-distortion measurements, BD-delta rate and SNR values, and complexity assessment data.

L-shaped region of width 4 samples luma for template search.

Inside the MB the residual is not included in the template representation; outside the MB it is.

Entropy coding is now independent of reconstruction in the design.

Send flag per partition – when set, the decoder infers the motion (no MVD ore ref idx in that case).

(didn't try using median of 3 candidates)

haven't yet tried larger block sizes

CS1 (random access) 4.1% for 32x32 MB size, 7.2% for 16x16 MB size.

CS2 (low delay) 4.2% for 32x32 MB size, 5.8% for 16x16 MB size.

BQTerrace 13% gain in CS2

Less gain when used with motion vector competition technique.

Factor of 2-5 in decoding time increase (may include pessimistic repetitive computations).

Skipping subpel refinement could save much of that, at about a 1% loss in performance.

Is it assumed that the whole picture is encoded in a single slice? Yes.

JCTVC-B099 [W.-J. Han (Samsung)] TE1: Verification results of RWTH JCTVC-B030 DMVD approach

This document presented verification results of RWTH approach for TE1: Decoder-side Motion Vector Derivation.

A total eight test cases were verified:

- CS1: default
- CS1: ExtMB = 0
- CS1: ExtMB = 0 and MVComp = 1
- CS1: MVComp = 1
- CS2: default
- CS2: ExtMB = 0
- CS2: ExtMB = 0 and MVComp = 1
- CS2: MVComp = 1

Source code was downloaded from the svn server provided by the proponent and the decoder binary were generated and used for the verification. Bit-streams for eight test cases and the corresponding scripts were also provided by the proponents.

For all cases, there is no reported problem to obtain the results and it was verified that the results provided from the proponent can be exactly reproduced without any problem.

Eight excel files including both the results from the proponent and the reproduced results are included.

JCTVC-B032 [M. Ueda, S. Fukushima (JVC)] TE1: Refinement Motion Compensation using Decoder-side Motion Estimation

In TE1 activity, Decoder-side Motion Vector Derivation (DMVD) tool has been evaluated for improving coding efficiency for HEVC.

This proposal focuses on the tool "Refinement Motion Compensation using Decoder-side Motion Estimation (RMC)". RMC was proposed in the previous proposal JCTVC-A108. The RMC tool aims to improve the quality of MC block in motion compensation process using DMVD process between reference pictures.

The RMC tool has been ported into TE1 codebase based on KTA2.6r1 because the first implementation was based on JM16.2 software. By the porting, the RMC tool has been available in TE1 activity.

Technique is for biprediction. One directioin MV is sent; the other is derived by this technique when indicated (flag per prediction block).

The simulation results show that the proposed technique provides the BD-bitrate savings of average 2% up to 3% for CS1 and 1.8% (2%, without class A case) up to 12% for CS2 under TE1 common conditions.

Decoding time 2.5x. Encoding time 1.6x.

It was remarked that the proposal was compared with IPPP coding, but this is a form of biprediction; thus it was suggest that it should be compared with forward-predictive B coding.

JCTVC-B105 [M. Tok, A. Krutz, A. Glantz, T. Sikora (TUB)] Cross-check result of JCTVC-B032 Refinement motion compensation using decoder-side motion estimation

The purpose of this document is to cross-check JCTVC-B032 on motion estimation at the decoder for motion estimation refinement submitted by JVC Kenwood Inc. (JVC). The verification task had reportedly been done successfully and the results reportedly matched those proposed in JCTVC-B032.

JVC provided win32 binary executable files of their proposed encoder and decoder, encoded bitstreams of all sequences agreed upon in the first description of the tool experiment], md5-checksums for the decoded sequences and their results. The provided bitstream files were decoded and bit rates, PSNR results, BD rates and checksums were compared.

The reported experimental results match those provided by JVC. The results are listed in JCTVC-B105_verification_results_CS1.xls and JCTVC-B105_verification_results_CS2.xls.

The results presented by JVC in JCTVC-B032 were reportedly confirmed.

It was remarked that cross-check verification should be more than running binaries and running scripts as-is.

JCTVC-B037 [S. Lin, M. Yang, J. Zhou, J. Song, D. Wang, H. Yang, J. Fu, H. Yu (Huawei), W. Yue, L. Zhang, S. Ma, W. Gao (Peking Univ.)] TE1: Huawei report on DMVD improvements

Simplification of template match search to use bilinear interpolation.

AIF filter applied when performing prediction

Lower complexity approach to prior DMVD scheme.

New variant aspect in proposal was not cross-checked.

CS1 6% savings with 32x32 MB; CS2 5%.

How much BD loss from the bilinear simplification? Not much – reported as about 0.1%.

presentation to be uploaded.

JCTVC-B048 [Y.-Jen Chiu, L. Xu, W. Zhang, H. Jiang (Intel)] TE1: Cross-checking of DMVD result from Huawei JCTVC-B037

This contribution contains a cross-checking result of JCTVC-B037 (Huawei). The software package obtained from SVN server dated on July 15 was reportedly successfully executing on Win32/64 PCs for both the STDM and simplified STDM (SIM_STDM) options under the CS1 and CS2 constraint sets.

The simulation demonstrates that the result of test cases a, b and d is consistent with the data provided by Huawei. For test case c, the simulation demonstrates an overall BD bitrate saving of 6% which is slightly higher than the reported improvement 5.9% by Huawei (reportedly due to Huaei using somewhat incorrect settings in config files).

An accompanied spreadsheet provided the detailed data of the results.

JCTVC-B047 [Y.-Jen Chiu, L. Xu, W. Zhang, H. Jiang (Intel)] TE1: Fast techniques to improve self derivation of motion estimation

This contribution presents the techniques to improve the derivation of motion vector at decoder (DMVD) side with the aim to increase coding efficiency of B pictures as well as to realize parallel friendly implementation of a video decoder. With the motion vector (MV) information self derived at video decoder side, the transmission of these MVs from video encoder side to video decoder side is skipped and thus better coding efficiency can be achieved. The proposed self derivation of motion estimation (SDME) techniques are reportedly friendly to the parallel implementation by utilizing on the temporal correlation among the available pixels in the previously-decoded reference pictures, instead of operating on the previously reconstructed pixels of the neighboring area of the current picture, which poses an inherent decoding ordering causal relationship among decoding blocks of current picture. Experiments have demonstrated that the BD bitrate improvement on top of ITU-T/VCEG Key Technology Area (KTA) Reference Software platform with an overall about 7.6% improvement on the hierarchical IbBbBbBbP coding structure under the test conditions with the block size 16x16 from the Tool Experiment group at JCT-VC. A fast version of the candidate based scheme has demonstrated an overall saving of the SDME computation time by about 94% with an overall 7.5% BD bitrate improvement. In addition, a parallel-friendly version to further remove the MV prediction neighbor dependency has shown an overall 6.8% improvement in BD bitrate reduction.

The ME block is bigger than the current block

Not using current picture area – instead matching areas of two reference pictures – for parallel friendly implementation.

Only applied to biprediction in B pictures.

Remark: With extended MB size, which was the planned setting for these experiments, the gain was reportedly about 3.8%.

Remark: Regarding the larger ME block used, how much gain is there from that, versus not using an extended MB size? Don't know offhand.

JCTVC-B069 [S. Sekiguchi, Y. Itani (Mitsubishi)] Report of TE1: Decoder-side motion vector derivation cross-check of JCTVC-A106 / JCTVC-B047

This contribution reported performance cross-check results on a Decoder-side Motion Vector Derivation (DMVD) tool proposed in JCTVC-A106 and JCTVC-B047.

Revision 1 uploaded

Read the software to verify the implementation – seemed OK.

According to the specification of TE1, they conducted the following cross-check experiments on the DMVD tool proposed in JCTVC-A106.

- Cross-check anchor bitstreams provided by TE1 technology proponents

- Run encoder software provided by the proponent
- Collect objective performance results in the form of BD-PSNR and BD-rate
- Collect encoding and decoding time of the software provided by the proponent

Used anchor streams generated by proponents. Results reported by Intel were reported as verified.

Speed measurements were reported as 4x slower decoding for full search; 1.6x slower for "fast mode".

JCTVC-B076 [Y.-W. Huang, C.-Y. Chen, C.-W. Hsu, J.-L. Lin, Y.-P. Tsai, J. An, S. Lei (MediaTek)] TE1: Decoder-side motion vector derivation with switchable template matching

This contribution describes MediaTek's work on decoder-side motion vector derivation (DMVD). In some prior work, template matching (TM) has been used to obtain motion information. In this proposal, it is suggested to adopt a switchable TM, and therefore two DMVD modes, DMVD_DIRECT and DMVD_TM, are provided. For DMVD_DIRECT, TM is disabled. A corresponding decoder utilizes only reference picture indices and motion vectors (MVs) of neighboring coding units (CUs) to derive motion information of a current CU with help from a corresponding encoder telling which spatial-temporal neighbors should be used. For DMVD_TM, TM is enabled. The TM search algorithm begins with an initial stage followed by a refinement stage. Moreover, adaptive template shape and boundary weighting are newly developed to improve the coding efficiency with low complexity overhead. Simulation results of two operating points are shown. The less complex operating point allows DMVD_DIRECT only. It achieves 5.4% and 5.6% average bit rate reductions for the TE1-DMVD Alpha and Gamma common test conditions, respectively, while the average decoding times are increased by 23% and 30% in comparison with the anchor that disables DMVD. For the more complex operating point, DMVD_DIRECT and DMVD_TM are both allowed. Average bitrate reductions become 7.2% and 7.7% for CS1/Alpha and CS2/Gamma, respectively, while the average decoding times are increased by 87% and 99%.

Also tested with motion vector competition and some other tools enabled – similar gain shown in this scenario as well.

Remark: This used a single slice per frame – it would be valuable to test multi-slice cases.

presentation deck to be uploaded

JCTVC-B119 [S. Klomp, J. Ostermann (LUH)] Cross-check result of DMVD implementation of MediaTek JCTVC-B076 (late)

This document contains results of cross-checking the software containing the tool "Decoder-Side Motion Vector Derivation with Switchable Template Matching" proposed by MediaTek Inc.

The software was provided on July,8 2010 by MediaTek Inc and bases on the KTA2.6r1 software. The cross-checking was done on a 64bit machine using the Linux distribution openSUSE 10.2.

The compilation using the provided Makefile finished without any errors. Tests with different sequences and rate points gave the same results on the encoder and the decoder. Furthermore, the PSNR and rate values are identical to the results published by MediaTek Inc. on July,9 2010.

Furthermore, compilation of the source code without the MediaTek Inc. contribution by deactivating the macro "DMVD_MEDIATEK" reportedly worked well.

JCTVC-B097 [W.-J. Chien, M. Karczewicz, P. Chen (Qualcomm)] TE1: Decoder-side motion vector derivation report from Qualcomm

This contribution presented a decoder-side motion vector derivation (DMVD) scheme with a multi-hypothesis control. The DMVD scheme used in this contribution is based on the template matching prediction method described in JVT-AA040. A multi-hypothesis control flag is signaled when the DMVD mode is selected and indicates how many hypotheses are used for motion compensation. Results show an average of 5.8% gain for IPPP configuration and 3.2% gain for hierarchical B configuration.

JMKTA 2.0 context.

Remark: Complexity impact of decision-making process to decide the number of hypotheses.

Remark: Not using extended Macroblock. Somewhat weaker anchor.

JCTVC-B068 [S. Sekiguchi, Y. Itani (Mitsubishi)] Performance evaluation on implicit direct vector derivation

This proposal is not directly part of TE1 – it is a somewhat different proposal, but on a closely related topic.

This contribution is to report coding performance of spatio-temporal adaptive direct vector derivation for B-skip/B-direct modes without explicit signaling that was proposed in our CfP submission at the last Dresden meeting. With this design, B-skip and B-direct modes do not need to send any side information for locally adaptive direct MV derivation relying on a simple decoder-side decision. A performance evaluation using JCTVC-A124 software, which has been chosen as the code base for TMuC software, was conducted and the result reportedly showed some coding gain. It was proposed to establish tool experiment for this category to identify relevant direct mode design to be included into test model.

The content of the TMuC document and software in regard to this topic seems somewhat unclear.

Average gain reported of approx 2.7% overall for proposal relative to spatial direct mode only. The TMuC software seems to also have some other method in it – disabled by default.

Proponent suggests creating a TE/CE to determine the best design for this aspect.

Consider result of break-out discussion on TMuC software status.

5.5 TE3: Inter prediction

JCTVC-B041 [X. Zheng (HiSilicon), H. Yu (Huawei)] TE3: Huawei & Hisilicon report on flexible motion partitioning coding

At the 1st JCT-VC meeting, TE3 was established to investigate the potential improvement on inter-frame coding. This contribution reports on investigation and refinement in the following three inter-coding areas:

- New representation method for block with two segments.
- Coding of block partitioning parameters.
- Improved motion vector prediction for non-AVC block partitioning.

It was reported that the compression capability of flexible motion partitioning can be further improved.

Average benefit 3.5% reported.

Continuation of TE effort was requested.

Difference between Qualcomm geometric partition and this method? The Qualcomm method involves signaling the row of intercept and the angle of intercept; in this scheme the two intersection points are indicated.

The software codebase was KTA. The proponent indicated a conjectured performance in the TMuC context to be similar, perhaps better.

JCTVC-B022 [S. Park, J. Sung, J. Young Park, B.-M. Jeon (LG)] TE3: Motion compensation with adaptive warped reference

This document presented experimental results of TE3 subtest 1, which aims to improve temporal prediction performance by using warping motion compensation. This tool uses an additional reference

picture which is a warped version of the original reference picture based on a "homography" relation between the current picture and the reference picture. The reported experimental results indicated 0.6% overall bit rate savings under constraint set 1 and 0.4% overall bitrate saving under constraint set 2, as compared with JM 17.0. In the context of an additional group of test video sequences having complex motion, the overall bit rate savings could reportedly be increased up to 12.4% and 3.8% respectively.

Four MVs are encoded to indicate the warp. The actual warp technique is derived from those – some details not fully understood by participants. Substantial complexity impact.

JCTVC-B104 [M. Tok, A. Krutz, A. Glantz, T. Sikora (TUB)] Cross-check result of JCTVC-B022 Motion compensation with adaptive warped reference picture

The purpose of this document was to cross-check JCTVC-B022 on motion compensation with adaptive warped reference picture submitted by LG Electronics Inc. (LGE). The verification task was reported to have been done successfully, with the results matching exactly those proposed in JCTVC-B022.

LGE provided a win64 binary executable file of their proposed decoder, encoded bitstreams of all sequences agreed upon in the first description of the corresponding tool experiment, and their results. The provided bitstream files were decoded and bit rates as well as PSNR results were compared.

The experimental results reportedly matched exactly those provided by LGE. The results were listed in JCTVC-B104_verification_results.xls.

It was remarked that binary executable cross-checking is not really what we're looking for in terms of proper cross-verification of proposed technology. Cross-verifiers are requested to carefully study and deeply analyze the algorithms and software as well as run programs.

JCTVC-B049 [P. Chen, W. Chien, R. Panchal, M. Karczewicz (Qualcomm)] Geometry motion partition

Results of geometry motion partitioning were presented in this contribution. The average bit rate reduction was reported as 4.3% for IPPP configuration and 3.9% for hierarchical-B configuration.

The reported encoder complexity was reported as approximately doubled.

The decoder also has some increased complexity (extra memory bandwidth).

JCTVC-B052 [A. Krutz, A. Glantz, T. Sikora (Tech. Univ. Berlin)] TE3: Adaptive global motion temporal prediction

This document presents the results for Subtest 1 of Tool Experiment 3 (Inter Prediction in HEVC). The tool presented herein is a prediction mode, i.e. Adaptive Global Motion Temporal Prediction (GMTP), for hybrid video coding environments that is based on global motion compensation and optionally on temporal filtering of spatially aligned pictures. Once a GMTP picture is available, the encoder chooses the macroblock types by means of rate-distortion optimization (RDO). If it chooses to encode a block using GMTP, only the type identifier is sent inside the macroblock header. No further information, e.g. coded block pattern, quantization parameters or coefficients are included in the bitstream for that block. This is a new GMTPSKIP mode.

The method has been evaluated using a set of 33 test sequences, including classes A to D of the CfP. The evaluation follows the experimental conditions of the TE3 experiment JCTVC-A303. The new prediction mode was incorporated into the JM 17.0 reference software.

Compared to gamma anchor. Used one warped reference frame.

Average 1% gain for class A. For class B, average 1% at high bit rate and 6% at low bit rate. For class C, average 2.2 at high rate and 2.8% at low bit rate. For class D, 1.9% at high bit rate and degradation at low bit rate. Sequences included those used for the subjective CfP test and also any others that were in the corresponding class in the MPEG CfP sequence candidate repository.

Some significant complexity impact was noted.

JCTVC-B060 [S. Park, B.-M. Jeon (LG)] TE3: cross-check result of JCTVC-B052 adaptive global motion temporal prediction

Withdrawn

JCTVC-B074 [M. Karczewicz, H.-C. Chuang, P. Chen, R. Joshi, W.-J. Chien (Qualcomm)] Rounding controls for bidirectional averaging

Two modifications for increasing the precision of bi-directional prediction and transform, when IBDI mode is not used, are proposed. The average BD rate reduction is 2.6% for IPPP configuration and 1.4% for hierarchical-B configuration. The results are obtained using TMuC 0.2.

Two aspects were proposed:

- Send rounding control - similar to prior KTA proposals VCEG-AI20 and VCEG-AI33.
- Increase the bit depth of transform processing.

With these modifications, the IBDI benefit shrinks to roughly 2.5% (which would be further reduced if the reference picture storage bit depth is decreased to 8 bits).

A suggestion made by a participant was to shift down some of the inverse transform precision between the horizontal and vertical stages, to prevent excess complexity through the transform processing stages.

JCTVC-B079 [S. Li, L. Yu (Zhejiang Univ.)] Second order prediction

This contribution proposes a method named Second Order Prediction (SOP) to exploit remaining spatial correlation of motion-compensated prediction residue by using intra prediction. The experiments results reportedly show that SOP can achieve an average 1.5% BD bit rate saving among B and C class sequence under constraint set 1 test conditions and 2% for constraint set 2.

Roughly 30% encoding time increased – testing 2 intra prediction modes (vertical and DC) during the motion search and then 9 modes after choosing a candidate motion vector.

JCTVC-B085 [L. Guo, P. Yin, E. Francois (Technicolor)] TE3: Simplified geometry block partitioning

This contribution provides a simplification of Geometry Block Partitioning (GEO) scheme as described in JCTVC-A121. Specifically, "Most Valuable Partitions" are proposed to achieve the best tradeoff between the complexity and coding efficiency. Most Valuable Partitions are derived from a statistical analysis of the actual used GEO partitions. For defined test conditions in TE3, for IPPP coding case, the simplified GEO mode reportedly gives an average 3% bit rate saving, which is very close to the performance of the initial reference GEO mode version, with a reduced complexity.

Decoder and syntax were not modified – the simplification is just for encoding.

JCTVC-B096 [N. Sprljan, S. Paschalakis, P. Wu (Mitsubishi Elect.)] Local intensity compensation for inter prediction in HEVC

This contribution presents new results for the Macroblock Weighted Prediction (MBWP) method for improved video coding efficiency. The basic concept of the presented method is to derive weighted prediction parameters adaptively at the macroblock and the sub-macroblock partitions levels, as opposed to the AVC standard where the weighted prediction are derived and transmitted at the picture level. The test platform has been described in JCTVC-A107. In this contribution a comparison was presented with other similar tools presented during the first JCT-VC meeting in response to the CfP for HEVC.

The various tested methods had similar performance, roughly 1% benefit overall.

5.6 MV prediction and coding

JCTVC-B023 [J. Lim, S. Park, B.-M. Jeon (LG)] Extended merging scheme using motion-hypothesis prediction

This document presented an extended merging process for inter prediction. In the merging process of TMuC, the current motion partition is predicted with one of two neighboring partitions, above and left partitions. In the proposed method, the merging process is combined with motion hypothesis prediction. When enabled, the current partition is predicted with the weighted sum of the two candidate partitions. One additional flag is signaled when condition is satisfied (merge_flag equal to 1, both neighboring partitions are available, and motion parameters of the two candidate partitions are different). The purpose of the proposed method is to enhance the coding efficiency of P picture by extending the current merging process. The simulation result shows that the proposed method achieves 2.9% and 3.3% bit rate reduction under Hier-P and IPPP condition on average for class B, C and D sequences. Moreover, the proposed method reportedly introduced negligible complexity increment relative to TMuC with the merging process.

Remark: Can achieve the same functionality by coding the picture as a B picture. Comparisons should perhaps be relative to what a B picture can accomplish. This aspect should be studied.

JCTVC-B061 [Y. Su, A. Segall (Sharp Labs)] Verification of JCTVC-B023 (Extended merging scheme using motion-hypothesis prediction)

This contribution reports verification results of JCTVC-B023 "Extended merging scheme using motion-hypothesis prediction" from LG Electronics. The verification package contains 1) bitstreams of the proposed scheme, 2) decoder *executable* of the proposed scheme and 3) spreadsheets for verification. The verification is carried out by 1) decoding the bitstreams, 2) collect PSNR/bitrate numbers and 3) verify that the numbers generated match those in the spreadsheets.

In summary, verification of JVTVC-B023 succeeded on the following test cases:

HierP on classB (100frames) sequences, classC sequences and classD sequences

IPPP on classB (100frames) sequences, classC sequences and classD sequences

In the accompanied spreadsheets, the verified numbers are shaded in blue color.

Again, executable is not our preferred method of verification.

JCTVC-B071 [T. Yoshino, S. Naito, S. Sakazawa (KDDI)] Refinement of skip coding mode for HEVC

As the inter coding scheme in AVC, the "skip" coding mode is effective as well as Inter16x16 mode especially under low bit rate condition. As the result of macroblock (MB) basis coding mode decision based on R-D optimization criteria, those two modes are frequently selected under the low bit rate condition because the R-D optimal point locates between those two candidates on the approximated R-D curve.

This contribution introduces an additional coding mode for P-picture based on extending conventional skip mode in order to improve coding performance for high resolution video. From experimental result, it was reported that an average bit rate reduction for IpPpP coding of 2.2% and 3.6% was achieved for the coding of all available sequences and for the coding of the HD sequences (1080p and 720p), respectively.

Remark: Seems like just an entropy coding alternative representation of zero motion vector delta with residual. Can analyze this as an entropy coding difference, and perhaps as a different way to decide what to do.

Further study was encouraged to determine where this gain is coming from, since that is not clear at present.

JCTVC-B072 [Y.-W. Chen, C.-H. Wu, C.-L. Lee, T.-W. Wang, W.-H. Peng (NCTU/ITRI)] MB Mode with joint application of template and block motion compensations

This contribution introduced a MB mode, termed the P+ mode, to improve the prediction efficiency of P-MBs by a joint application of template and block motion compensations. The motion vector (MV) found by minimizing template matching error is viewed as an additional free MV, which can contribute to estimating pixel intensities in a P-MB. As in POBMC (of JCTVC-A123), the predictors derived from the template and block MVs are linearly combined based on a distance weighting criterion. In particular, given that the template MV tends to minimize the prediction error in the upper left quarter of a MB, the block MV search criterion is changed so that the resulting MV can contribute more to minimizing the error in the remaining part. When applied to 16x16 P-MBs, the proposed scheme is observed to have an average BD-Rate saving of 2.4% and a corresponding BD-PSNR gain of 0.1 dB. It achieves the highest rate saving (4.2%) in S03 (Kimono, Class B) and the lowest (0.4%) in S10 (PartyScene, Class C).

Sort of another way to introduce biprediction for a P picture. Should compare to B picture. Similar issue to JCTVC-B023 in terms of analysis.

The contributor indicated that they did not have time to test with B pictures.

JCTVC-B081 [K. Sato (Sony)] Proposals for improved MV coding

Motion vector competition scheme was proposed in VCEG-AC06 and has been implemented into the KTA software. Most responses to the HEVC CfP employ this scheme.

For further improvement this contribution proposed a dynamic code number assignment for motion vector predictors. The proposed method reportedly also improves subjective quality between the moving object and still background in fixed-camera-view sequences.

Test results are needed – but are not yet available.

Question: Within a given test sequence, how often would the selection change?

Question: Benefit of set order selection that is at sequence level in JCTVC-A124 to be moved to slice/picture level.

JCTVC-B094 [F. Bossen, P. Kosse (DOCOMO USA Labs)] Simplified motion vector coding method

A method for coding motion vector data was presented. It was based on the method previously proposed in document JCTVC-A114. It reportedly achieves coding efficiency similar to the methods included in the TMuC software while providing reduced complexity by simplification of the parsing of motion vector data and reducing the number of motion vector predictors.

It seems like there is an opportunity for complexity reduction and for elimination of duplicate functionality.

JCTVC-B108 [E. Maani, W. Liu, A. Tabatabai (Sony)] Multi-parameter motion (MPM)

In this document, a motion compensation that uses of multiple prediction blocks was proposed – similar in concept to Flierl/Wiegand/Girod multi-hypothesis.

Have only tested with two MVs – pointing to same reference picture.

Similar comment to others: should compare to B, not P.

JCTVC-B101 [G. Clare, J. Jung, S. Pateux (Orange Labs)] Preliminary results on motion vector prediction

Was presented Thursday a.m. as evaluation of TMuC behavior.

5.7 Intra prediction

JCTVC-B021 [J. Kim, S.-W. Park, J.-Y. Park, B.-M. Jeon (LG)] Intra chroma prediction using inter channel correlation

This contribution presents a new intra chroma prediction mode which utilizes the correlation between chroma and luma samples. In the proposed method, chroma samples are predicted from the reconstructed luma samples around the prediction block by modeling chroma samples as a linear function of luma samples. A flag is signaled to indicate whether the proposed method is used or not. For the simulation, the test conditions comply with the Intra Prediction AHG report (JCTVC-B004). The proposed method is implemented on top of JM-KTA 2.6rl and the simulation results are compared to those of JM-KTA 2.6rl without any modification. Coding efficiency is evaluated based on the two QP range sets, the lower 4 QP values {22, 26, 30, 34} and the higher 4 QP values {26, 30, 34, 38}. In the case of intra only coding, the average BD-rate improvements about the luma components are 1.59% and 1.56% at each QP range set. In the case of Constraint Set 1 of the CfP, the average BD-rate improvements are 0.88% at the lower 4 QP values and 0.97% at the higher 4 QP values. On the chroma components, the average BD-rate improvements about U components are 5.11% and 7.42% at each QP range set in the case of intra only coding. The average BD-rate improvements are 5.25% and 7.27% at the lower and the higher QP values respectively in the case of Constraint Set 1. The average BD-rate improvements about V components are 4.09% and 5.72% at each QP range set in the case of intra only coding. The average BD-rate improvements are 4.26% and 5.88% at the lower and the higher QP values respectively in the case of Constraint Set 1.

Scheme of prediction "chroma = alpha times luma plus beta", factors alpha and beta derived by least squares optimization. Usage is signaled per 8x8 block. Parameters are derived at the decoder from surrounding MBs, current implementation is most likely floating point

55% of chroma blocks are coded by the scheme.

BD Gain is approx. 1.6% on average, wherein the individual gain for color is higher

Question arises how this would map to subjective improvement, or whether potentially coding artifacts might become more visible

Further study was recommended.

JCTVC-B025 [Y. H. Tan, C. Yeo, Z. Li, S. Rahardja (I2R)] Intra-prediction with adaptive sub-sampling

Intra-prediction improves coding performance by reducing inter-pixel redundancy. However, to accommodate the use of block transforms, not all pixels can be predicted from reconstructed pixels that are located close to themselves. This causes prediction performance to suffer as pixel values further apart are less correlated. This proposal presents additional intra-prediction modes designed with the goal of improving prediction performance. Experimental results show an average gain of about 2% when the new modes are incorporated in the current 8x8 prediction modes. Since the new coding modes (8x8) are designed with transform size smaller than coding block size, the modes can also be useful when the prediction unit is larger than the maximum transform size.

Interleaving of prediction blocks where a subset is first encoded and decoded to serve as a predictor for subsequent subsets. Subsampling methods are horizontal and vertical interleaving, and 4 adjacent blocks. Transform is applied on the subsets. Scheme was only implemented on 8x8 prediction units (could be done on larger units also). Currently only 4x4 transform is used. All other prediction modes are still used. Gain reported is 2% on average for intra (implementation based on KTA 2.6r1)

It was remarked that the scheme could be difficult to operate in pipeline systems, because each 4x4 prediticion unit must be reconstructed before the next can be predicted.

Further study was encouraged; this needs implementation for other block sizes before its merits can be assessed.

JCTVC-B027 [K. Iguchi, A. Ichigaya, Y. Shishikui (NHK), S. Sekiguchi, A. Minezawa (Mitsubishi)] Performance report of iterative adjustment intra prediction

This contribution presents the detailed process of Iterative Adjustment Intra Prediction proposed in JCTVC-A122 and experimental results. JM 16.2 with the proposed prediction tool achieves approximately 0.7%, 1.8% and 1.8% bit-saving on average for Y, U and V signal respectively under the alpha anchor conditions with intra only coding.

Iterative adjustment is done by loop: Take reconstruction of L-shaped neighborhood/initialise current block by mean value of neighboring blocks -> DCT/zero-setting of high-frequency coefficients/IDCT (next iteration uses original reconstructed values of neighborhood again).

Maximum iteration number is 10 for 16x16, 4 for 4x4 blocks. Significant increase in complexity, contributor mentions "several times" computation time for encoder, but unclear how much at decoder.

Results with JM16. For classes A, B and super-resolution (8Kx4K sequences) luma BD gain is 1% on average, for lower resolution classes C-E 0.5%.

Contribution noted.

JCTVC-B033 [K. Iwata, S. Mochizuki, R. Hashimoto (Renesas)] Intra prediction based on repetitive pixel replenishment

The contribution reports improved performance results of intra prediction based on repetitive pixel replenishment. The simulation results showed that predicted image created by the method had an average of 1.14 dB and up to 2.76 dB PSNR gain for luminance against anchor of CfP. These results also showed an average of 1.32 dB, 1.54 dB and up to 3.58 dB, 3.55 dB PSNR gain for chrominance, respectively. The proposed method is implemented on Test model under consideration (TMuC) software.

Usage of template matching. Search range is 33 samples horizontally and 16 samples vertically Prediction. Full search is used, Prediction is composed from two best candidates (i.e. roughly 500 operations per sample is necessary at encoder, displacement vector is encoded).

Result only for two sequences Basketball and BQMall 4.78 and 4.0 % bitrate reduction for intra only coding (basis for simulation is TMuC 0.1).

Further study was encouraged, more complete results are necessary to figure out the merits.

JCTVC-B040 [C. Lai, Y. Lin (HiSilicon)] New intra prediction using the correlation between pixels and lines

A new spatial prediction scheme is presented for intra encoding by taking full use of the correlation between lines and pixels instead of blocks. Unlike the traditional block-based intra prediction, the spatial correlation is explored by using the line-based and resample-based intra prediction to improve compression performance of intra encoding. Compared with H.264/AVC High Profile under CfP ALPHA testing condition except that GOP structure is all intra pictures, the new experimental results shows an average 5.07% bit rate saving for all sequences, and about 5.71% average for HD (720P, 1080P and 1600P).

Refers to JCTVC-A025 and JCTVC-A111 Goal to perform prediction from close-by samples; line-based intra prediction 1x16, 16x1 (for 16x16 blocks), 2x8, 8x2 (for 8x8 blocks); nine directional modes implemented for each which are realized by shifting the block rows/columns circularly before the prediction and transform; DCT of corresponding size is applied. Another approach is made by interleaving horizontally plus vertically.

Only for 8x8 and 16x16 blocks currently

This increases (due to lots of additional modes that need to be checked) the encoder complexity significantly, but at the decoder the additional complexity is less (except for need to implement additional versions of DCT, pixel shifts etc.)

Implementation into KTA6.2r1. Average bitrate saving is roughly 5%, by tendency slightly higher for low rates, and also for higher resolutions.

Recommend for TE, supported also by MSRA

JCTVC-B042 [A. Tanizawa, J. Yamaguchi, T. Shiodera T. Chujoh, T. Yamakage (Toshiba)] Improvement of intra coding by bidirectional Intra Prediction and One-dimensional directional unified transform

This contribution introduces an intra prediction method combining two AVC based intra prediction (BIP: Bi-directional Intra Prediction) and combinations of pre-defined 1-D transforms depending on the intra prediction direction (1DDUT: 1 Dimensional Directional Unified Transform). BIP and DUT were included in the CfP submission of JCTVC-A117 [1]. 1DDUT is an improvement of DUT to increase the BD-rate gain.

A test was conducted under the test condition of the Transform AHG. For I slice only coding structure, the average BD-rate gain is 3.72% for BIP, 5.64% for 1DDUT and 8.76% for the combination of BIP and 1DDUT. For CS1 coding structure, the average BD-rate gain is 2.06% for BIP, 2.35% for 1DDUT and 4.16% for the combination of BIP and 1DDUT.

Refers to VCEG-AE14 and JCTVC-A117. BIP and weighted sub-block coding order. Directional unified transform (type A and B) based on scanning the field of prediction samples in various sequences depending on prediction direction.

Transform basis is said to have been trained on a set of data outside the sequences under test. In a first step, matrices were trained for each directional mode, in a second step the unification is done by clustering the residuals of the directional prediction based on correlation statistics and selecting the two bases with best performance.

Bi-directional prediction increases encoder complexity by factor 1.5, decoder complexity only marginally.

Results based on KTA: 3.7% for BIP only, 5.6% for 1D-DUT, 8.7% for combinations with transform (for I only coding). In terms of coding gain, almost same performance as MDDT, but simplification claimed. Currently works for block sizes up to 16x16.

It was suggested to study this in a TE (BIP only) provided that supporting partner is found.

JCTVC-B063 [T. Yamamoto, Y. Yasugi (Sharp)] Flexible representation of intra prediction modes

In this contribution, FDMR (Flexible Directional Mode Representation) is introduced as a novel intra prediction mode representation. The functionalities achieved by introducing FDMR are (1) simple probable mode derivation process, (2) use of the rank order of the intra prediction modes in the probable mode derivation process, and (3) use of more than one probable mode. Those functionalities provide flexibility and extensibility as well as the increase of coding efficiency.

Idea to derive intra prediction modes at the decoder side e.g. by analysis of the modes used in the neighborhood. Use 2 "probable modes" when many candidates or at least two with same probability exist; Usage of the derivation is signaled, otherwise the usual mode encoding in performed. Adaptation of "probable mode" derivation also possible by encoding the mode rank order.

Average gain in case of sending the rank order is 0.3 % for case of 2 probable modes and mode rank encoding are used.

Contribution noted.

JCTVC-B067 [S. Sekiguchi, A. Minezawa (Mitsubishi), K. Iguchi, Y. Shishikui (NHK)] DCT-based noise filtering for intra prediction samples

This contribution reports experimental results on a noise filtering method to intra prediction samples, based on the iterative adjustment intra prediction (IAIP) mode proposed in JCTVC-A122. The IAIP mode tries to get better intra prediction samples especially for texture with moderate gradation by involving

continuity between target prediction samples and neighboring reference samples. It applies DCT to an image region covering the block to be predicted and its neighboring decoded samples, then inversely transforms the coefficients after cutting off of some high frequency components. By repeating this process, characteristics of neighboring samples can effectively be incorporated into the prediction samples. In this contribution, we applied this idea for noise filtering on intra prediction sample generated by angular multi-dimensional intra prediction (ADI) modes, which has been included into TMuC. The proposed filtering just applies DCT once to an image region consisting of intra prediction samples derived from ADI process and its spatially neighboring blocks, then inversely transforms after cutting high frequency coefficients. The experimental result shows that the proposed approach could improve intra coding performance of ADI modes even without use of adaptive reference sample smoothing scheme.

Goal to improve prediction in top-right area of the predicted block. Approach is to use the DCT-domain prediction similar to JCTVC-B027 as post-processing of usual directional prediction, but not operated interatively (i.e. setting high-frequency components of the prediction block to zero effects a kind of noise suppression).

Simulations in JCTVC-A124 software (not TMuC or stripped 124 pre-TMuC). Average gain reported is 2.3% for high-resolution sequences (class B, A and 8Kx4K).

Gain seems not to be high, but the approach to apply de-noising or some kind of loop filtering in the intra prediction could be worthwhile (not necessarily in the DCT domain!) Compare to other contributions that go in similar direction.

Further study should be performed in context of loop/deblocking filters

JCTVC-B078 [C. Guillemot, T. Poirier (INRIA), and L. Guillo (IRISA/CNRS)] Intra prediction by a linear combination of template matching predictors

In intra mode, a prediction block is formed by extrapolating pixels neighbouring the current block to be coded. It is then subtracted from the current block prior encoding the resulting residual. When blocks have regular textures, this method is efficient. However, predicting blocks with more complex textures in this way is less adapted. This contribution presents an intra prediction technique using template matching enhanced by a weighting factor computed by a one step matching pursuit approach. This method can be seen as a generalization of the template matching method in which the weighting factor is not “1”. It is also more general in the sense that it can lead to a linear combination of blocks which will best approximate the template, hence the block to be predicted. This only tool has been integrated in KTA2.7 and compared with the original KTA2.7. Classes and videos used are those selected by the Intra AhG. All pictures were encoded as Intra. Improvements related to videos belonging to the classes A, B1 and D are scarcely significant. However, average gains for videos belonging to the classes C, E and B2 are respectively (+0.17dB, -2.56%), (+0.19dB, -3.33%) and (+0.17dB, -3.79%).

The comtributors interpret templates as atoms; these are re-ordered in a dictionary and subsequently compacted to allow fast search. Three best fitting atoms are averaged.

Results were evaluated in the KTA2.7 context. Current complexity at encoder and decoder is dramatically higher. (used for block sizes up to 16x16) Average gain is estimated around 2-2.5% (data only given per class and separate for low and high QP ranges). For the BQMall and Basketball sequences, gains are comparable (one slightly lower, one slightly higher) than the one used in JCTVC-B033. Size of search window was not exactly communicated, but could be slightly smaller than for JCTVC-B033.

Further study was encouraged.

JCTVC-B080 [Y. Chen, L. Yu (Zhejiang Univ.)] Decoder-derived adaptive intra prediction

In this document, a new intra prediction scheme is proposed to improve prediction accuracy and capture the dynamics of different video contents. The scheme adaptively generates optimal intra prediction modes according to the local feature of the coded video. The optimization is conducted by analytical calculations to minimize the prediction residue energy. Experimental results show that the scheme outperforms H.264/AVC in all CFP test sequences and is especially effective for high resolution sequences. Compared to H.264/AVC, the proposed scheme achieves 2.86% average bit rate reduction for all CFP test sequences

(Class A to Class E) and 4.42% average bit rate reduction for high resolution sequences (Class A and Class B).

Interpretation of inter prediction as linear matrix operation with boundary pixels as input. Optimize weights in matrix such that the prediction residual is minimized. Derivation is performed at the decoder, usage is signaled to the decoder. Per prediction direction and per block size (4x4 and 8x8) one matrix of size (number of boundary pixels x number of pixels in block) is optimized. Frequency of optimizations is not clearly stated.

Implemented in KTA 2.1. Average gain 2.8 % bitrate saving; higher gains are found for higher resolution sequences, and also by tendency for higher rate.

Encoder run time increase is by less than 2 times, decoder more than 2 times.

Investigation shows that the percentage of usage is also higher for the higher resolutions.

Further study was encouraged, requires significant reduction of complexity (in particular decoder)

JCTVC-B093 [F. Bossen (DOCOMO USA Labs), TK Tan, J. Takiue (NTT DOCOMO)] Simplified angular intra prediction

This contribution presents simulation results using several configurations of the intra prediction tools integrated into the TMuC software. The comparison shows that angular intra prediction performs the best. A simplified angular intra prediction method is also presented and compared. It achieves the same coding efficiency as angular prediction but with reduced complexity.

In TMuC, ADI (arbitrary direction I) and ANG (angular prediction) have very similar effect. It was found that angular prediction has better performance; a simplification of ANG is proposed as well. For negative angles, the main reference is extended, such that the side reference is no longer necessary. This saves the current division and sample testing.

Original TMuC uses ANG for 8x8 and ADI for other sizes.

Results show that switching off ADI totally does not decrease the gain significantly (only in 4 cases losses in the range of 0.1-0.2 %), whereas the loss due to the simplification is marginal.

It was suggested to establish TE to include this method.

JCTVC-B100 [J. H. Min, S. Lee, I. K. Kim, W. J. Han (Samsung), J. Lainema, K. Ugur (Nokia)] Unification of the directional intra prediction methods in TMuC

This contribution proposes unification of the two directional intra prediction approaches (ADI introduced in JCTVC-A124 and Angular Intra Prediction introduced in JCTVC-A119) which were included in the initial TMuC design in the first JCT-VC meeting. The proposed unified approach provides a single clean design for TMuC intra prediction and is reported to provide an Intra picture coding efficiency improvement of around 1.4% over the default TMuC configuration and around 2.8% improvement over TMuC 0.1.

The proposal was to unify ADI and ANG prediction versions and use that as the future default in TMuC. Report performance by doing this

ADI only (as in 124 or TMuC 0.1) as reference

Switching of ANG and ADI depending on block size roughly 1.4% BR decrease

ANG only roughly 2.9% BR decrease

Unification of ANG and ADI roughly 3.4% BR decrease

(Part of the gain is possibly due to allowing more prediction directions in 4x4 modes)

This was further discussed along with the report given by the TMuC breakout group (see section on TMuC).

JCTVC-B118 [M. Budagavi (TI)] Angular intra prediction and ADI simplification (LATE)

In HEVC TMuC Intra prediction, pixels in current block are predicted from their neighboring left and top pixels. Two different types of Intra prediction mechanisms are defined: Angular intra prediction and Arbitrary Direction Intra (ADI). In both these techniques, the reference pixels used for Intra prediction at a particular pixel location in the predicted block are determined by solving an equation for line which involves calculation of slope. Slope calculation involves division which is expensive to implement in both hardware and software. This contribution proposes modified versions of Intra prediction equations that involve additions/multiplications with simple factors instead of expensive divisions.

Propose to replace the division in ANG in the calculation of the angle through a multiplication with the reciprocal. Performance difference is 0.01 % bitrate increase overall.

Comment: By implementing JCTVC-B093, the division would not be there anymore. Study in context of same TE.

JCTVC-B109 [E. Maani, W. Liu, A. Tabatabai (Sony)] Differential coding of intra modes (DCIM)

Spatial domain directional intra prediction has been used to reduce the correlation between the samples in the current block and the reconstructed neighbors. In AVC, 8 directional prediction modes (plus the DC prediction mode) are defined. The prediction direction is signaled to the decoder using a simple predictive coding method. The current intra prediction has two major disadvantages: 1) the small number of directions does not provide sufficient precision to cover arbitrary directional patterns; and 2) the mode number prediction from neighbors is not accurate enough to exploit the geometric dependency between blocks. Increasing the number of directions typically results in a lower residual energy, however, the cost for signaling the prediction mode may also increase significantly such that little gain is observed. This is especially the case for small block sizes such as 4x4 or 8x8. To address this problem, in this submission, we propose a new method to accurately predict the intra directions from the reconstructed neighboring pixels and differentially encode the intra directions. This allows a more precise directional prediction without significant increase in the cost for transmitting the side information. Simulation results show that the new intra prediction method can provide as much as 13% bitrate reduction compared to AVC intra prediction.

The purpose of the contribution is to have efficient signalling of prediction direction, in particular for small block sizes (previously proposed in JCTVC-A030). Direction derived by output of Sobel operator (including confidence measure). Based on the confidence measure, a delta angle is derived, such that the possible range of directions is restricted (when predictive mode is used)

Question: Does the derivation influence the latency of pipelining at the decoder side? Derivation is not instantaneous, Computation of 2x2 matrix eigenvectors is necessary for this.

Parsing is influenced by decoder (reconstruction) output, no clear separation. This could be a problem.

Differential signaling is done by unary code (1 bit flag expressing the usage of the prediction). Gain reported is 5.5%.

Was not used together with MDDT yet. There is no guarantee that current MDDT gains are additive, because it may be that the prediction error is increased .

Also not clear whether similar gain would be possible with TMuC (larger number of prediction directions etc.)

It was suggested to establish a related TE, and also investigate how this relates to the method of prediction direction prediction that is already in the TMuC; the complexity at the decoder should also be further investigated.

JCTVC-B112 [J. Zhao, A. Segall (Sharp Labs)] Parallel prediction unit for parallel intra coding

The concept of a parallel prediction unit (PPU) is proposed within the Test Model under Consideration (TMuC) design. The goal of the parallel prediction unit is to define a group of pixels that are intra-coded, and where the intra-coding may be done in a parallel fashion. This extends previous work on parallel intra-prediction for a H.264/AVC-like macro-block to the TMuC design. Parallelization is achieved by partitioning the intra-coded blocks into two sets and predicting the first set completely from the pixels bounding the PPU. The second set of blocks is then predicted from the reconstructed, first set of blocks. To be clear, blocks within each set are predicted in parallel. Results are reported using TMuC 0.3 where it is asserted that the parallelism results in negligible impact on coding efficiency. For example, the coding efficiency impact for 1080p sequences (hierarchical B) is 0.012dB or less than 0.5%

Refers to previous proposal JCTVC-A105: First-pass and second-pass blocks arranged as checkerboard, where the second pass allows to perform prediction from the right and bottom as well.

Implemented in TMuC 0.48% BR increase for hier. B, and 0.25% for IPPP, and 0.5% for intra-only coding (latter only for 16 frames per sequence). (Results for high resolution – slightly higher for small resolution)

Comments: Parallel processing also possible with diagonal stripe processing; needs to be clarified whether high amount of parallelism at MB level is necessary, or whether this has to be paid off against other complications (of this specific algorithm)

Question: Would the checkerboard become visible?

TE to be established, provided that at least one other interested party is found

JCTVC-B102 [X. Zhao (CAS), L. Zhang, S. Ma, W. Gao (Peking Univ.)] Mode-dependent residual reordering for intra prediction residual

In this contribution, a mode-dependent residual reordering (MDRR) method is proposed to further simplify the mode-dependent directional transform (MDDT) for Intra coding. 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 the spatial domain. The reordering is manipulated in a way that the distribution statistics of reordered residual samples present less mode-dependent characteristics. 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 reduced from original 18, 18 and 8 to the proposed 3, 3 and 3 for I4MB, I8MB and I16MB, respectively. Experimental results show that, under the testing condition specified in the AhG report on alternative transforms with all-Intra conditions, compared with MDDT, an average BD rate increase of 0.1% and BD PSNR drop of -0.005dB was reportedly observed.

The contribution was noted and discussed.

JCTVC-B117 [P. Tao, D. Li, W. Wu, J. Wen (Tsinghua Univ.)] Intra prediction using localized horizontal spatial prediction (LATE)

This document proposed using localized horizontal spatial prediction in the intra block prediction. In the proposed algorithm, a region of size 32x16 is divided into two 16x16 MBs, consisting of the samples from the even-numbered columns and the odd-numbered columns (termed the even MB or EMB and the odd MB or OMB) respectively. The EMB is encoded using conventional intra coding techniques and then its reconstruction is used for the prediction of the OMB. Experimental results reportedly show that with CABAC coding, an average of 0.9% bit rate savings can reportedly be achieved for all sequences, with 1.2% for HD sequences for all-intra coding. Somewhat more gain was shown with CAVLC coding.

Similar in spirit to field coding, rotated. It was remarked that coding the data using one coded field followed by another coded field that uses inter prediction from the first field might actually work better.

Testing was in the JM (all-intra) context. Testing in the TMuC context seems desirable.

It was remarked that the upsampling filter would extend beyond the MB boundaries.

Division of 32x16 MB into two vertically interleaved blocks ("even MB and odd MB") EMB is intra coded, six-tap filter interpolation applied for prediction of OMB. Average BR reduction over classes A-D in all-intra coding is 2.9% for CAVLC coding and 0.9% for CABAC (1.2% for HD).

Further study – somewhat surprising that it gives (little) gain at all. Would that be transferable to TMuC? Further, how is the 6-tap upsampling filter working at the block boundaries? It should not use samples from neighbored MBs.

Conclusions from Intra prediction discussions

The following general conclusions were reached in regard to activities on intra prediction:

- Proceed with harmonization of intra prediction in TMuC as suggested in JCTVC-B100.
- Further investigate JCTVC-B093 and JCTVC-B118 in a TE (simplification to be verified for adoption by next meeting).
- TE planning and analysis: Concentrate on methods with reasonable gain without adding significant complexity.
- Establish some TE relating to JCTVC-B040, JCTVC-B042 (bidirectional part) - investigate in common TMuC environment
- Establish some TE relating to JCTVC-B109 in relation to the method of prediction direction prediction that is already in the TMuC
- Establish some TE relating to JCTVC-B112 provided that other interested party is found
- Suggest further study (AHG ?) of (see above) within TMuC environment

5.8 Residual transforms

JCTVC-B024 [C. Yeo, Y. H. Tan, Z. Li, S. Rahardja (I2R)] Mode-dependent fast separable KLT for block-based intra coding

Mode-Dependent Directional Transform (MDDT) was previously introduced to improve transform coding of intra-predicted blocks [1], and is now a core component of the Test Model under Consideration (TMuC) [2]. 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 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.

Proposal to replace MDDT (consisting of two separable KLT bases) by a separable transform that consists of a DCT and a KLT (both implemented as integer transforms). DCT as fast algorithm, KLT also reducing computations by half compared to full matrix multiplications.

Implemented in KTA, performance very similar to the MDDT that is implemented there (different in range of +/- 0.3% BR fluctuation, by tendency sightly better for large and slightly worse fo small resolutions. (Note: The MDDT of KTA was optimized with QCIF, whereas the MDDT of TMuC is different)

Recommendation: TE establishment.

JCTVC-B038 [D. Wang, J. Song, H. Yang, M. Yang, H. Yu (Huawei), Xin Zhao, Siwei Ma (Peking Univ.)] Performance improved directional transform techniques

This document reports the two updated techniques on directional transform since the last meeting. The first one is the directional multiple transform (DMT) for inter residual blocks. Based on the direction information of the residual signal, multiple transforms are used, which are trained offline, in order to match the texture feature of the residues. With improved temporal predictive coding and syntax embedding implemented, the performance gain is further improved. The other technique is the rate distortion optimized transform (RDOT) for intra residual blocks, as described in detail in [2]. The transforms and the coefficient scanning order are further optimized and the performance gain is increased, under the discussed Transform AhG test condition. Moreover, since the selection of the transform used on one block is decided at encoder side, it does not introduce extra computation complexity at decoder side.

Directional Multiple Transform (DMT) introduces possibility to select between DCT or one of eight different (trained) directional transforms (KLT) for inter prediction blocks. Syntax is split into a flag that selects DCT or DirT and one element that selects the transform.

Training of transforms is using QCIF and CIF data outside of the training set. Classification is made on direction characteristics.

Implementation in KTA2.6r1, new transforms only used for 8x8 block case. Performance gain approx. 1.2% for CS1, 2.4% for CS2. 30% are 8x8, 50% of these are using directional transforms.

Rate Distortion Optimized Transform (RDOT) is a similar concept (choice of different transforms) instead of MDDT. Signaled at the MB level whether RDOT is used, then 2 different transforms (per hor/vert direction) in case of 4x4 blocks, which makes a possible 4 combinations to be checked and signaled in each mode. 4 different transforms, i.e. 16 combinations in case of 8x8 blocks.

Gain approx. 2% compared to MDDT

Encoding time of RDOT is 4.5x increased (early break in mode decision), decoding time 1.25x. No clear numbers available for DMT.

Further study – requires complete implementation of DMT, currently RDOT appears to add complexity without giving high bitrate reduction.

JCTVC-B039 [H. Yang, J, Zhou, H. Yu (Huawei)] Simplified MDDT (SMDDT) for intra prediction residual

Combined with the directional intra prediction technique in AVC, MDDT (Mode Dependent Directional Transform) has been proven to be an efficient tool to enhance the coding efficiency by exploiting the redundancy in the intra prediction residuals. Based on the symmetry among all intra prediction directions, the number of transform matrices can be significantly reduced by the proposed SMDDT (Simplified MDDT) while the coding performance is kept unchanged. We suggest that a joint intra prediction and transform TE/CE is established, and various joint directional prediction and transform techniques for intra coding can be studied together.

Use same transform matrices and scan orders for different directions, instead of 16 transform bases and 8 scan orders only 5 transform matrices and 3 scan orders are used

Roughly 0.1-0.3% bit rate decrease compared to the KLT MDDT.

Saves memory, but does not save computational power compared to the KLT MDDT.

However, the approach does require additional matrix transposition.

For training, CIF and 720p sequences outside of the test set were used.

Comparison againt the MDDT of TMuC would be necessary to assess advantages.

Recommendation: TE

JCTVC-B102 [X. Zhao (CAS), L. Zhang, S. Ma, W. Gao (Peking Univ.)] Mode-dependent residual reordering for intra prediction residual

In this contribution, a mode-dependent residual reordering (MDRR) method is proposed to further simplify the mode-dependent directional transform (MDDT) for Intra coding. 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 reduced from original 18, 18 and 8 to the proposed 3, 3 and 3 for I4MB, I8MB and I16MB, respectively. Experimental results show that, under the testing condition specified in the AhG report on alternative transforms with all-Intra conditions, compared with MDDT, average BD rate increase of 0.1% and BD PSNR drop of -0.005dB is observed.

Mode-dependent residual reordering.

Note 1: Similar approach as JCTVC-B039, but classification is different. Only 3 different transform bases and 3 scan directions are needed, performance increase compared to original MDDT 0.1% average.

Note 2: Similar classification scheme in JCTVC-B024

This contribution better fits to transform category.

Recommendation: TE establishment.

JCTVC-B073 [W. Ding, Y. Shi, B. Yin (Beijing Univ. Tech.)] Fast mode dependent directional transform via butterfly-style transform and subsequent integer lifting steps

Mode Dependent Directional Transform (MDDT) can improve the coding efficiency of H.264/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 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 be implemented on hardware very easily.

Replacement of MDDT by orthogonal transform that can be implemented in butterfly/lifting structure. All multiplications can be implemented as shifts.

Bitrate loss compared to MDDT roughly 0.15% overall.

Complexity-wise comparable to JCTVC-B024.

Recommendation: TE establishment.

JCTVC-B092 [R. Cohen, A. Vetro, H. Sun (Mitsubishi)] Performance of direction-adaptive residual transforms

The primary purpose of this contribution is to summarize the coding performance of a direction-adaptive residual transform, using software and test conditions proposed by the Ad Hoc Group on Alternative Transforms. JM-KTA 2.6r1 is used as an experimental platform, with an alternative 8x8 transform that performs 1-D DCTs along aligned directional paths within prediction residual blocks. A rate-distortion optimized decision process is used to select among the conventional 2-D transform and several directional transforms for 8x8 blocks. These alternative transforms are available for transforming both Inter and Intra prediction residuals. Experimental results are given for Hierarchical-B, IPP and all-Intra configurations. Subjective differences in visual quality are discussed as well.

Directional transforms in addition to 2D DCT both in cases of intra and inter

Conventional transforms without training, usage of existing quantizers

Simulation in KTA, directional transform in 8x8 mode

Gain is roughly 0.3-0.4 % for Hier. B and IPPP, and 0.7-0.8% for Intra only (compared to KTA with MDDT off).

Slight visual improvement is claimed in the case of using more directions.

Roughly 30% runtime increase in case of inter. Hardly justified by the small gain.

Benefit or disadvantage compared to MDDT not clear from the results that are presented.

JCTVC-B107 [C. Auyeung, A. Tabatabai (Sony)] Intra coding with directional DCT and directional DWT

The Mode Dependent Directional Transform (MDDT) is an option in KTA2.6r1 for the coding of intra block residue. To reduce complexity of MDDT, two types of transforms are proposed to replace MDDT for the transform coding of intra block residuals: Directional Discrete Cosine Transforms (DDCT) and Directional Discrete Wavelet Transform (DDWT). They are applied along and perpendicular to the direction of the intra prediction mode on either 4x4 or 8x8 blocks. In addition, fixed scanning pattern, which is a function of QP and prediction direction, for scanning of the transform coefficients is also proposed. DDCT results in BD-Rate of -1.78% and BD-PSNR of 0.067 dB relative to DCT for CS1. In contrast, MDDT results in BD-Rate of -2.33% and BD-PSNR of 0.087 dB relative to DCT for CS1.

This document proposes to conduct experiment with DDCT as a part of the Transform Tool Experiment of HEVC.

Directional DCT: Re-ordering into a non-rectangular shape where the previous directional orientation becomes horizontal; approach similar to SADCT of MPEG-4.

Quantization similar to MDDT, scanning different.

Implementation in KTA2.6r1.

For inter, approx. 1% worse than MDDT, for all intra, 1.5% worse than MDDT.

Note: For some sequences, DDCT is better than MDDT.

SADCT requires variable length of DCT to be implemented – is this really a complexity advantage?

Contribution noted.

Conclusions on alternative transforms:

- Establish TE on methods for MDDT simplification: JCTVC-B024, JCTVC-B042 (1DDUT part) JCTVC-B039/JCTVC-B102, JCTVC-B073
- investigate in common TMuC environment

Suggest further study of documents as indicated above within TMuC environment

General Note: If the gain of TMuC vs. AVC in intra only is worse than for inter, it appears important to investigate improvements, though the overall (statistically 20-25% intra rate) gain may be low; it is important for difficult sequences with large amount of intra coding.

5.9 Loop filtering

Also see JCTVC-B043.

JCTVC-B045 [T. Chujoh, T. Watanabe, T. Yamakage (Toshiba)] Adaptive spatial-temporal prediction of filter coefficients for in-loop filter

There were quite a few responses to the CfP that adopt Wiener-based in-loop filtering. QALF (Quadtree-based Adaptive Loop Filter) is a variant of such Wiener-based in-loop filtering that introduces a quadtree-based data structure to indicate the region to apply the filter. In TMuC (Test Model under Consideration), a similar scheme was included. The scheme uses spatial prediction of the filter coefficients to reduce the redundancy.

In this contribution, a method of adaptive filter coefficient prediction was proposed to further reduce the redundancy. This included a temporal direct prediction mode that reuses the previous filter coefficients and a spatial and temporal adaptive prediction mode.

This scheme shows 0.2% bit rate reduction on average under the test conditions of in-loop filtering ad-hoc group. This is reportedly about 40% bit rate reduction of filter coefficient representation bits.

The proposal is for encoder to select between temporal and spatial prediction of filter coefficients.

Question: Loss propagation characteristics?

TMuC has spatial prediction, with coefficients sent in slice header.

For further study.

JCTVC-B056 [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. senda (NEC)] Performance report of modified conditional joint deblocking-debanding filter

This contribution presents a modified version of the conditional joint deblocking-debanding filter described in JCTVC-A104. The modified conditional joint deblocking-debanding filter integrates comfort noise injection into its filtering process and uses predetermined small pseudo noise which is generated by applying high-band-pass filter to random values drown from uniform distribution. The addition of the small pseudo noise to the deblock-filtered image masks banding-noise. Simulation results reportedly show that the modified version significantly reduces the banding-noise with a negligible impact on video coding efficiency. It is proposed that the modified conditional joint deblocking-debanding filter is studied in TE/CE on in-loop filter for Test Model.

Negligible effect on PSNR performance.

Two prior relevant contributions JVT-C056 and Q15-B-15.

Even without IBDI, negligible objective performance difference.

Plan further work as TE.

JCTVC-B064 [T. Ikai, T. Yamamoto, Y. Kitaura (Sharp)] A parallel adaptive loop filter

This contribution is related to the In-loop filtering ad hoc group. In this contribution an adaptive Wiener-based filter technique was proposed. The proposed technique uses two inputs: the de-blocking filtered reconstruction signal and the unfiltered reconstruction signal. The proposed technique also provides the functionality to process the two inputs in parallel. The reported experiment results indicate that the proposed technique provides 1.2% bitrate reduction (equivalently 0.04 dB gain) on average over all test conditions (CS1 and CS2) , compared with QALF.

The primary motivation is to enable parallel filtering processing.

Question: Does the parallel structure let blocking artifacts bypass the deblocking filter.

Comment: If the filtering operates on a block basis, it can be structured for spatially parallel processing.

Question: How to derive the weight factor? Used Wiener filter approach.

JCTVC-B075 [J. Yang, K. Won, H. Yang, B. Jeon (SKKU), J. Lim, J. Song (SKT)] In-loop deblocking filtering for intra blocks

In AVC, the deblocking filter is designed to reduce blocking artifacts caused by block-based prediction and quantization. However, the deblocking filtering process does not pay full attention to intra blocks. In this proposal, an adaptive deblocking filter was proposed with special attention to intra blocks. Using coding information related to the intra blocks such as intra prediction modes, the proposed method makes adaptation of the filter to each given intra blocks. Simulation results were given under the test conditions CS1 and CS2 which are set by in-loop filtering AHG. Additional results were also given under all intra coding condition.

Alters the boundary strength computation for intra. Uses the prediction direction to guide the boundary strength selection.

Examples of significant perceptual improvement were shown.

JCTVC-B077 [Y.-W. Huang, C.-M. Fu, C.-Y. Chen, C.-Y. Tsai, Y. Gao, J. An, K. Zhang, S. Lei (MediaTek)] In-loop adaptive restoration

This contribution describes MediaTek's work on in-loop adaptive restoration (AR). The framework of AR is composed of three stages including improved deblocking filter (IDF), quadtree-based adaptive restoration (QAR), and picture-based adaptive offset (PAO). IDF is a modification of the AVC deblocking filter for intra coding units (CUs). QAR can split a picture into multi-level quadtree partitions, and each partition can be enhanced by Wiener filtering or band offset or edge offset. PAO classifies pixels into different groups and calculates an offset for each group. IDF, QAR, and PAO are all adaptive restoration methods reducing errors between reconstructed pixels and original pixels of a current picture. Simulation results show that in comparison with the in-loop filtering ad-hoc group (AHG) anchor which enables quadtree-based adaptive loop filter (QALF), internal bit depth increase (IBDI), and other KTA tools, the proposed AR can reportedly achieve 3.8% and 3.6% bit rate reductions for random access and low delay IPPP test conditions, respectively. The encoding complexity is reportedly increased by 6% and 21% for random access and low delay IPPP, respectively, and the decoder complexity is reportedly increased by 14% and 10%, respectively.

Some aspects are similar to JCTVC-B075.

JCTVC-B110 [C. Auyeung, A. Tabatabai (Sony)] Separable adaptive loop filter

In this proposal, separable and non-separable loop filters were compared. To provide better trade-off of complexity and subjective quality, this document proposes to allow the encoder and decoder to switch between non-separable filters and separable filters. In particular for the hierarchical B coding structure, non-separable filters were applied to filter the I pictures and the separable filters were applied to filter the P and B pictures.

This document proposes a tool-experiment to compare the performance of non-separable and separable loop filters.

The proposal was tested under test conditions established in the in-loop filtering AHG.

The software context was KTA2.6r1 with quadtree adaptive loop filtering, with support for separable filtering added.

If all pictures are coded separably versus all pictures coded non-separably, there are reportedly substantially more artifacts in the separable case. If only the I picture is filtered non-separably, this effect is reportedly substantially mitigated (although not entirely eliminated).

A participant asked whether it might be adequate to use non-separable filtering for an I picture and not perform the adaptive loop filter for the other pictures. This may merit further investigation.

JCTVC-B095 [I. S. Chong, W.-J. Chien, N. Malayath, M. Karczewicz (Qualcomm)] Encoder complexity analysis and performance report on adaptive loop filter

In this contribution, encoder complexity aspects of various proposed Adaptive In-Loop Filter (ALF) algorithms are evaluated along with their coding efficiencies. A performance report according to the ALF method categories mentioned in the AHG report on in-loop filtering JCTVC-B007 was presented, i.e., i) separate QT vs. CU synchronized and ii) filter shapes and types.

It was suggested to establish the following guidelines for the work:

- Avoid extreme amounts of multi-pass processing for encoding experiments (e.g., 18 pass non-separable and 34-pass separable filter designs), and
- Consider post-filtering in the evaluation of filtering methods.

The group agreed with these suggestions.

It was noted that one filtering pass can potentially be avoided in the encoder if the filter is a post filter.

It was reported that there may not be a benefit to using a separate quadtree for the filter, relative to that used for the coding units.

Subjective quality evaluation results were not reported – which are clearly desired.

JCTVC-B113 [A. Segall, Y. Su (Sharp Labs)] Codeword restrictions for improved coding efficiency

It was proposed to modify the clipping points that follow the motion compensation and adaptive loop filtering processes. In terms of performance, improvements were reported for image sequences with high contrast but with sample values that do not cover the full input dynamic range. For example, it was reported that the BQSquare sequence coding performance was improved by 3% and 1.9% for Hierarchical-B and IPPP coding, respectively, with the modified clip points. It was suggested that this be considered a bug fix for the HEVC design. The proponent recommended adoption of the technique into the TMuC.

This was part of proposal JCTVC-A105.

It was asked whether adding clipping as a post-processing stage would give the same performance, and the proponent indicated that although that provides some significant portion of the benefit, it helps to include the clipping within the loop.

It was remarked that similar clipping is included in the JCTVC-B077 scheme.

The average gain was not reported, but was estimated by the authors of JCTVC-B077 to be about 0.5%.

Proposed syntax is to put the clipping in the picture parameter set level.

It was remarked that having the special flag for the [16..235] range may not be advisable. The name "codeword" may also be somewhat confusing. The position of the codeword_restrict_sameC_data_flag should perhaps be shifted to after the codeword_restrict_maxCr element.

It was suggested that this has somewhat similar functionality to the JCTVC-A124 approach for content adaptive dynamic range (CADR).

Encoder specifies the value limits (low/high) for each frame. Clipping is performed based on this at the output of the MC as well as the output of the loop filter. Gain reported as roughly 3% BR reduction for BQSquare.

Note: To avoid latency, it may be necessary to use the range data of the last frame.

Relationship with JCTVC-A124 dynamic range expansion and clipping – JCTVC-B113 seems to be simpler.

Some concern raised about complexity even of the clipping which requires 2 compare operations per sample.

Explore in CE: Performance over entire set; comparison against only output clipping (outside loop), and clipping only at MC output (not at the loop filter). Things to study include average gain, output (post-decoding) clipping, clipping only in one of the two places versus in both places.

5.10 Motion compensation interpolation filtering

JCTVC-B043 [A. Tanizawa, T. Chujoh, T. Yamakage (Toshiba)] Synergistic effect of high accuracy interpolation filter (HAIF) and quad-tree based adaptive loop filter (QALF)

Many kinds of interpolation filtering technique were proposed at the 1st JCT-VC meeting in Dresden in response to the Call for Proposals. The contribution JCTVC-A117 proposed the combination of High Accuracy Interpolation Filter (HAIF) and Quad-tree based Adaptive Loop Filter (QALF) to achieve additional coding gain compared to the stand-alone usage of each tool.

This contribution shows simulation results of HAIF, QALF, and the combination of HAIF and QALF. If only HAIF is introduced on top of AVC, there are a few sequences that show significant coding gain, while some sequences show loss. However, if HAIF is introduced in conjunction with QALF, additional gain on QALF was reportedly always observed. For the IPPP coding structure, a "synergistic" effect of HAIF and QALF was reported. In the experimental results, for the IPPP coding structure, the combination of HAIF and QALF reportedly achieved a gain of 2.3% beyond the sum of the gains aof HAIF only and QALF only.

The test results were reported from the KTA software context.

It was suggested that evaluations of motion compensation interpolation filtering should be performed with adaptive loop filtering enabled, and vice-versa.

Main suggestion made by the proponents is that in the context of investigating interpolation filters the loop filter should be switched on.

In general, the interdependency of loop filter and interpolation filter seems not to be fully understood.

JCTVC-B051 [S. Matsuo, Y. Bandoh, S. Takamura, H. Jozawa (NTT)] Region-based adaptive interpolation filter

This document proposes enhancement of the adaptive interpolation filtering (AIF) scheme, relative to that in the KTA software. As characterized by the proponent, "conventional AIF" optimizes the filter coefficients on a frame-by-frame basis. When an original image has uniform texture or movement, conventional AIF was suggested to be adequate. However, the proponent asserted that when the image has multiple movement areas or when different regions of the image have different texture characteristics, the coding efficiency could be improved by using region-by-region interpolation filtering. The proposal was implemented in the KTA software to evaluate its performance.

With the anchor being KTA 2.6r1, the average BD-rate gain for P frames of the proposal, compared to SAIF, was reportedly about 0.6% (SAIF: 5.0%, proposal: 5.6%) for the HEVC CfP sequences. The maximum reported gain was about 2.3% (SAIF: 4.3%, proposal: 6.6%) for the sequence "Cactus".

Various schemes were considered regarding how to divide the image into regions for region-adaptivity purposes. The encoder was designed to choose between these various methods using a rate-distortion criterion.

However, only two frames were actually coded for the experiments. Any results from such a test should be considered very preliminary.

Further study on such techniques is encouraged (hopefully without excess complexity).

A participant remarked that other region classification methods may be better, such as detail structure of local region, prediction error energy.

JCTVC-B083 [T. Suzuki (Sony)] Study of MC interpolation filter for bi-prediction

A bi-pred/single-pred motion compensation filter switching was proposed in the JCTVC-A103 response of Call for Proposala. This contribution provided additional information about this subject. In this technique, motion compensation interpolation filters are designed for single prediction and bi-prediction. The motion compensation filter sets are switched if the macroblock prediction mode is single predictive or bi-predictive at the macroblock level. A two tap bi-linear low pass filter is applied when a macroblock is encoded as bi-predictive, and this reportedly removes high frequency component too much in some cases. The coding efficiency can reportedly be improved by enhancing middle frequency response for bi-prediction. This contribution provides simulation results for this tool. The average BD bit rate gain is reportedly about 1.0%, with the maximum gain being about 14.9%. This contribution also provided some complexity analysis.

Lower encoder complexity for this scheme than SIFO (switched interpolation filter with offset), because the encoder does not need to choose which filter to apply – always one particular filter for bi-prediction and one other particular filter for single prediction.

The proponent indicated that some sequences outside of the CfP test set provided better performance.

Note: This proposal has no effect on I or P pictures.

The quarter-pel positions were derived directly in this design – which may have some effect on the measured performance.

It was remarked that the SIFO technique is not properly supported in conjunction with IBDI.

It was noted that although the average gain is not so significant, the gain on a couple of sequences was substantial.

Further study was encouraged.

General usage (for P and bi-prediction) of fixed 6-tap separable interpolation filters, having higher preservation of high frequency than the usual AVC filters. Further claim that bi prediction averaging loses high spatial frequency – therefore further incease of mid frequency in this case

Quarter-pel positions are derived directly (no additional bilinear filter to derive them from half-pel positions).

Complexity of encoder is less than for SAIF, because the second pass of motion compensation after derivation of adaptive filter coefficients is not necessary.

Gain shown on average (compared to SAIF) is around 1% in BR reduction.

IBDI is off, which may have an influence on the performance of SAIF that is compared against.

5.11 TE4: Variable length coding and other contributions on entropy coding

JCTVC-B070 [K. Sugimoto, S. Sekiguchi, Y. Isu, Y. Itani, A. Minezawa (Mitsubishi)] Proposal on improved entropy coding method for DCT coefficients

This contribution proposed an entropy coding method for DCT coefficients in large transform block. Adding a flag to signal the last position of existence of DCT coefficient greater than one improves coding efficiency especially for noisy video contents. In this contribution, we applied this idea on the JCTVC-A124 software[1], which is the base code for TMuC software. Simulation results show that the proposed approach improves the conventional AVC/H.264 method for A, B and SHV sequences.

It was reportedly found by statistical analysis that longer runs of "trailing ones" are occuring for larger transform block sizes. To address this, it was proposed t use a "last more significant" (LMS) flag to signal the position of the last coefficient with level larger than one. This reportedly saves bits on level encoding. The average gain reported on class B and larger is reported to be 0.5-0.6% bit rate reduction. The effect

seems to be dominant for noisy sequences (e.g. Nebuta festival 4% reduction). The reported improvement was mainly for luma in P and B pictures.

If de-noising is performed as pre-processing, it was suggested that the gain would almost disappear.

The typical gain seems to be in the 0.1-0.2% BR reduction range. The technique adds complexity (one additional condition to be checked in transform coefficient decoding).

Conclusion: Further study was suggested.

JCTVC-B091 [H. Zhu (Zhu)] Improvement of arithmetic coding based on probability aggregation

This proposal is a proposed improvement version of the JCTVC-A027. The two improvements are as follows:

1) Word based input and output

2) Improved logProb table of logprobaddvl[64][2].

The proponent was not available to present the contribution.

JCTVC-B098 [M. Karczewicz, P. Chen, W.-J. Chien, X. Wang (Qualcomm)] Variable length coding for coded block flag and large transform

This contribution presents a coding scheme for coded block flag using variable length code. According to the scheme, coded block flags at coding unit level from all Y, U and V components are grouped and coded together. For each component, coded block flags at block level are also grouped and coded together. In both cases, coded block flags from neighboring coding unit or neighboring blocks are used as context in selecting a VLC table. Simulation results show that an average gain of 2.6% can be achieved in coding efficiency.

Large transform (i.e. transform larger than 8x8) coding using variable length code is also presented in the contribution. For large transforms, this contribution proposes that only the first 64 coefficients based on scan order are kept and coded. Simulations show that such a solution provides a coding gain over interleaved transform for both intra and inter predicted blocks.

Proposal to group and code CBF of Y, U and V together, and use neighbored CBF as context.

Report average BR reduction of 2.6% in both cases of CS1 and CS2.

Further proposes to apply the interleaving technique on large transforms differently for first 64 coefficients. Gain reported 2.2% for all-intra, 2.7% for IPPP (no results on hierarchical B).

Gain of CBF and transform claimed to be additive

Establish TE (Nokia, Tandberg participate).

A participant remarked that the current implementation of VLC in TMuC software appears to be not optimum in RDO. Wait with the experiment until this is fixed (mid September according to work plan).

5.12 Quantization

JCTVC-B035 [X. Yu, D. He, E.-h. Yang (RIM)] Improved quantization for HEVC

This contribution proposed a quantization scheme for residual coding based on adaptive reconstruction levels, consisting of three steps:

- First, a "hard decision" quantization is performed: quantization with a rounding offset being zero is conducted, and a reconstruction level is computed as the centroid for each quantization output.
- Second, fixing the reconstruction level for each quantization output, an RDOQ algorithm is applied to re-calculate quantization outputs.

- Third, given the quantization decision by RDOQ, the reconstruction levels are updated.

Simulation results reportedly show 0.2 to 0.5 dB gain, compared with RDOQ.

Non-uniform reconstruction was advocated. In this proposal, the encoder sends three values q1, q2, and q on a frame basis – separately for each block size (10 bits each). For i=0, the reconstruction is 0. For |i|=1, the reconstruction is sign(i)*q1. For |i|=2, the reconstruction is sign(i)*q2. For |i|>2, reconstruction is i*q.

This scheme was reportedly tested in the TMuC 0.2 context.

Intra MB usage was disabled for non-I frames, and the technique was not applied to I frames – this was due to the spatial prediction in I frames that causes the reconstruction to affect the prediction of the subsequent blocks.

A 2-15% bit rate improvement per sequence was reported for the non-I frames with this scheme (relative to intra-disabled reference). Only 8 frames were coded for each sequence.

It was remarked that a prior relevant contribution was JVT-P053.

It was remarked by a participant that both the distortion and bit rate change significantly relative to the reference. The number of bits was lower and the PSNR was lower when using the technique – which is somewhat like increasing the QP value.

The short sequence provides less opportunity for error propagation relative to the I frame. The gain seemed best for low-activity sequences – i.e., sequences that rely more on the I frame.

It was remarked that just having the encoder optimally choose a separate QP value for each transform block size might provide some gain.

A participant remarked that for rate control or perceptual reasons, an encoder would change the QP value within a picture – which would affect that ability to use this scheme.

A participant suggested adjusting lambda for a given QP.

A participant noted that the relationship between QP and lambda may be different in the TMuC than in prior designs.

The results seemed somewhat preliminary. There needs to be some way to deal with intra and spatially-adaptive QP selection. And it should be tested relative to using a larger QP in the reference to produce a more similar bit rate and PSNR operating point.

However the concept seems interesting and potentially promising in some form.

Further notes:

Design like rate-constrained Lloyd Max but also taking into account the necessary rate for side info for encoding the reconstruction table of a non-uniform quantizer by yet another lambda-times-rate term.

Proposal to signal only the two innermost reconstruction levels and the stepsize for the outer levels (each by 10 bits). This is done separately for each DCT size.

It is a two-pass encoding process: Encoding is done by uniform quantization first, computing centroids of two innermost reconstruction levels and the q value (for distance of the outer reconstruction levels). These are used for the non-uniform quantizer used in final quantization (RDOQ-like).

It is strange that in the reported results are lower in bitrate and in PSNR as compared to the TMuC results. Apparently, this corresponds to a larger QP value. This could have implications as it is similar to having a larger QP variation between I and P. (this explains relatively larger gain in low activity sequences such as Vidyo).

Only 8 frames were encoded per sequence, results reported for class C, D and E

The current method does not allow change of QP below slice level.

Intra disabled, currently only applied for P pictures, Rate gain reported counts only the P pictures.

Results are preliminary, but further investigation necessary on issues above to take any action.

JCTVC-B059 [J. Zheng (HiSilicon & Huawei)] Adaptive frequency weighting quantization in macroblock level

(refers to previous JCTVC-A111 and JCTVC-A028) Usage of parameterized frequency weighting models (instead of direct specification of quant matrices) at picture level – assign weighting parameters to frequency bands; those weighting factors are also shared by transforms of different block sizes. Switch quant matrix on or off at MB level. Syntax allows usage of different weighting modes (up to 7 excluding case of weighting off) that can be selected. Mode to be selected at MB levels can also be encoded dependent on modes of adjacent MBs, and on MB type.

Adapted once per frame.

Results reported from KTA experimentation using 2 different adaptive quant are around 3% BR saving for class B and C, only around 0.5% for class D.

Not compared against AQMS from KTA (which gives PSNR losses versus flat quant)

Not clear yet how it would be implemented in TMuC

Concern raised about restricted flexibility due to parameterized weighting

Not clear how weigthing parameters at picture level are determined. Orally it is said that it depends on number and relevance of coefficients found in the respective band; depending on the subjective importance of the band, the weight is either increased or decreased compared to the default (which is determined from a standard visual model)

Unclear how frequency weigthing can increase PSNR (that uses flat weighting of quadratic errors) – may this be due to the unequal quantization of picture types that is happening in the local adaptation?

The following aspects were recommend for further study:

- Better explain how the model parameters are derived.
- Propose how to combine this into TMuC.
- Justify the necessity of up to 7 models.
- Analyse how the effective quantization step size is adapted in various frame types.

6 Application area specific contributions

JCTVC-B031 [K. Kazui, J.Koyama, A.Nakagawa (Fujitsu)] Proposal of requirement on very low delay coding

Low delay less than 100 ms. In CBR applications, usage of I refresh picture (due to buffering) would violate this constrained. Approach: "Intra MB line refresh" (horizontal or vertical, only part of picture is refreshed). Reference to non-refreshed area should be prohibited (encoder issue). It is however necessary to have a new slice boundary at the boundary of the refreshed MB row (in order to guarantee decodability). Such a scheme introduces overhead, i.e. loses quality. This is in particular true for the vertical scheme.

Proposal to introduce information about position of refreshed area in the slice/picture header. "Asymmetric limitation of reference" disallows references from a refreshed area to a non-refreshed area. Also, de-blocking filtering using samples from non-refreshed areas must be disallowed, and motion compensation taking reference from non-refreshed areas shall be disallowed, therefore it is suggested to define extension/extrapolation from refreshed into non-refreshed areas of reference pictures.

No results were shown to illustrate that the suggested method really provides a benefit in terms of compression.

It is not high priority currently to include specialized measures like this in the TMuC design. Current TMuC software does not support multiple slices per picture yet.

Constrained intra prediction also should in principle provide similar functionality.

Further study was recommended, more results would need to be presented.

JCTVC-B084 [C. Lan, J. Xu, F. Wu, G. J. Sullivan (Microsoft)] Screen content coding

Screen content (computer generated, not camera generated) was not explicitly mentioned in the HEVC project requirements. Such content reportedly has very different statistics – no noise, sharp edges, smooth motion. Two new coding tools were proposed: Residual scalar quantization (intra prediction, bypassing the transform, scalar quantization with deadzone like APEC in KTA); index map for colors (like vector quantization); each block represented by 1-4 colors and index.

The proposed tools were implemented in the JM; and the results reportedly show for one image "mix" and a normal webpage gain around 10 db vs. TMuC; less for a PowerPoint presentation slide.

It was remarked that it would be more interesting to also test with other material, e.g. animated graphics, mixture of video and graphics, scrolling text etc.

It was remarked that adapting QP might help for HEVC.

Was comparison made against GIF, JPEG-XR? No

Would it be a good idea to burden any decoder by implementing these tools?

It was remarked that other standards bodies (Wireless HD) are looking into this issue.

It was remarked that wireless desktop is an important topic, but industry is looking for other ways of doing it (e.g. JPEG-XR) and it should be avoided to use many different ways of doing it.

Another opinion expressed was that most probably, HEVC will face the necessity to encode mixed content. Therefore the design should take care of this.

A further opinion expressed was that if specific tools would be designed for this, they should be absolutely light-weight and potentially be switched on the profile level. Delay may also be an issue. Scalability may be important.

It was agreed to establish AHG to further study the subject and applications.

JCTVC-B062 [M. Zhou (TI)] Sub-picture based raster scanning coding order for HEVC UHD video coding

One of the application areas of HEVC is ultra high definition (UHD) video coding, in which the picture size can go up to 8K x 4K (7680 x 4320). The large search range required for the UHD video coding poses a great challenge for chip design in terms of on-chip memory size and memory bandwidth. In this contribution, it was proposed to enable sub-picture based raster scanning order in the HEVC to facilitate the cost-effective UHD video designs.

Discusses vertical motion versus horizontal motion referencing – suggesting a preferred limitation of vertical search range relative to horizontal search range.

It was proposed to use rectangular picture area scanning for wide pictures, with some limitation of both horizontal and vertical search range. The concept is similar to use of slice group map type 2, but not necessarily requiring multiple slices.

It was remarked that providing excessive freedom to an encoder in such usage could result in making it more difficult to decode rather than less.

For UHD (8Kx4K and beyond) it is necessary to constrain memory accesses (picture size increases faster than memory bandwidth). One solution could be restriction of vertical search range (not limiting horizontal). Another solution is growing window. Sub-picture raster scanning order (simlar to FMO type 2) would also restrict horizontal search range (and cause overlap and therefore increased memory accesses). With search range of +/- 256x256 applied to an 8Kx4K picture size, the need for on-chip memory is reduced to approx. 25% with 6 sub-partition columns compared to no usage of sub-partitions.

A participant remarked that the number of columns should not become high to avoid too much necessary variability on the decoder implementation.

Reduction of on-chip memory seems to converge approximately beyond K=4 columns.

JCTVC-B066 [S. Sekiguchi, K. Sugimoto, S. Yamagishi, Y. Yamada (Mitsubishi)] Report of Super Hi-Vision coding performance

This contribution reported the performance of Super Hi-Vision (SHV) coding with the design proposed in JCTVC-A107. That design supports fundamental coding tools that are similar to those that have been proposed in several CfP submissions and adopted in the TMuC at the last (Dresden) meeting. Experimental results reported in this document were asserted to show that use of these tools contributes to significant coding gain for super high vision (SHV) source video, which is an area of focus for the HEVC standard.

Substantial gain on such video was reported. The use of an extended block size and adaptive Wiener filtering were asserted to be important to this gain.

The contribution compared the JCTVC-A107 design against AVC anchors for the 8Kx4K test sequences "Steam Locomotive" (SL) and "Nebuta Festival" (NF). Roughly 57% BR reduction was reported for SL, and 25% for NF. It was reported that a substantial amount of larger-size blocks were used for both intra and inter coding in these experiments.

There was some discussion about the source video sequences.

Nebuta is a night capture – very noisy

The original video for this content was shot using quincunx sampling and then interpolation upsampling, while full sampling would be preferable. However, the provider indicated that this should not be a major problem. Eventually, source video from a full resolution 8Kx4K camera may become available, although it may contain significant source noise due to sensor characteristics. It was suggested that HEVC should be designed for robustness to such noise.

It was remarked that noise robustness seems to be increased by increasing the coding block sizes.

The study of coding behavior of the TMuC design on SHV sequences was suggested.

A participant remarked that the search range used in the experiments might be somewhat small for SHV. In regard to the "steam locomotive train" video sequence in particular, it was remarked that the motion search range for this sequence should be very large. 128x128 search range appears low for the case of 8Kx4K.

It was asked whether the SHV sequences have been studied to determine their actual native resolution: is the effective detail of the sequences really matching with 8Kx4K resolution? This does not seem to have yet been fully studied.

Further study of SHV coding behavior, especially in the TMuC context, was encouraged.

7 Performance measurement methodology and source video test material

JCTVC-B020 [D. Alfonso (STMicro)] Proposals for video coding complexity assessment

This contribution discussed some methods that are reportedly commonly used to estimate the complexity of software applications, and it proposed a methodology for the complexity assessment of video coding software systems based on the "Valgrind" tool suite.

The contribution suggested the following proposals for JCT-VC consideration:

- To consider complexity assessment during the standardization process of HEVC and to evaluate contributions in terms of both coding efficiency and complexity efficiency.
- To define a clear procedure for complexity assessment considering the present contribution as a starting point for further discussion.
- To specify the complexity assessment procedure in a document entitled e.g. "Recommended simulation common conditions for complexity efficiency experiments".

Measuring computational complexity by execution time may be misleading as it e.g. includes CPU idle time, system access time etc. This could partially be resolved by measuring user time only, but examples of various identical AVC encoder runs reportedly show that even such numbers can exhibit considerable variation. Other measures such as cycles per instruction are also highly CPU dependent.

It was suggested to measure the instruction count per program execution. The instruction count in Linux profiling (instruction and data cache simulator) is e.g. identical to the number of accesses to the instruction cache. Furthermore, the number of data cache accesses is proportional to memory bandwidth.

The results also reportedly show that the index of dispersion (indicating variation) is very low in these measurements.

It was remarked that we should be cautious about using a particular simulation software as a substitute for true algorithmic complexity.

One subject that was raised in discussion was how to estimate hardware implementation complexity. It was remarked that this methodology does not give a means to measure hardware complexity.

The tool also measures implementation complexity, not algorithmic complexity – i.e. it provides results that are dependent on degree of optimization)

A participant asked whether the Valgrind tool provides consistent results across different machines, and it was reported that it should.

It was noted that the software tool that was proposed involves a dramatic slow-down of running speed, while our software is already very slow. CPU-specific profiling can also provide some useful information, although not with cross-platform consistent results.

It was noted that the proponent did not assert that a complexity measurement methodology should be considered a substitute for discussion and expert analysis.

It was suggested to investigate this type of analysis for longer term application – although right now it is extremely obvious that the current software is so inefficient as to make this kind of analysis unnecessary or inappropriate to identify issues.

To make it practical, would it only be necessary to run on few sequences? Perhaps not – there is certainly sequence dependency.

It was questioned how much additional information this methodology would give. The current TMuC, for example, has many places where reductions in run-time could easily be made. These places can also be found by conventional profiling (without a need for a cache simulator, and without increasing runtime substantially).

Activity in this area, at least in the longer term, should include analysis of both software and hardware complexity.

It was agreed to establish an ad hoc group on complexity measurement to further investigate these issues.

JCTVC-B055 [K. Senzaki, K. Chono, H. Aoki, J. Tajime, Y. senda (NEC)] BD-PSNR/rate computation tool for five data points

This contribution presented a BD-PSNR/Rate computation tool for five data points. The new BD-PSNR/Rate computation tool is based on C code, and computes BD-PSNR/Rate values in the same manner as the Excel macros embedded in JCTVC-A031. Unlike the Excel macros, the C-code can be compiled on any platform. The compiled binary executable is friendly to batch processing, and its usage is very similar to that of AVSNR4 which many of the JCT-VC experts are familiar with. The BD-PSNR/Rate mismatch between the C-code and the Excel macros is reportedly negligibly small. The appended C code was proposed as the BD-PSNR/Rate computation tool for five data points for the future activities of JCT-VC.

This software seems useful for experiments that will use five data points rather than four, although we are currently using four for most planned experiments. The contributor was thanked for the contribution.

It was remarked that the JCTVC-A031 macros can be used for higher-order evaluations as well as 4 or 5 point scenarios.

JCTVC-B058 [T. Dove (TestVid)] Video test sequences

This document described video test sequences that are being offered by TestVid for use by MPEG, ITU-T SG16 and JCT-VC for video compression testing.

This was an initial proposal by TestVid, for discussion at the meeting. TestVid had made an estimate of the sequences that might be required, and would reportedly welcome comments / requests for changes to the formats / contents / durations of the sequences, to match what is actually required.

TestVid indicated that most of their sequences use typical 2D video formats, with two sequences being 3D stereographic.

The indicated that various video resolutions, bit depths, and chroma formats could be provided – esp. 1280x720 to 2048x1152, including 4:2:2 10 bit per sample. They have some 4:4:4, 14 bit, etc.

In terms of acquisition systems – they reportedly use a variety, so as to collect material representing a variety of characteristics.

The video sequences were described as primarily "contribution quality" – usually after some (e.g., built into camera) compression process.

The offered license conditions for use were as follows: Licensed for the development and promotion of video-related ITU/ISO/IEC standards, without charge / royalty fees. The license conditions being:

- the sequences cannot be incorporated into any other test video sequences, even in a substantially modified form
- they cannot be re-sold or supplied by other organisations / companies
- they are to be used for research and development purposes only (e.g. not for trade shows or other commercial purposes)
- the logo on the bottom left corner may not be removed or obscured
- TestVid is stated as the copyright owner when any sequences are provided (and this is also mentioned in standards documents and the like).

The contributor was asked about potential use of the sequences for scientific research and publications, and the contributor indicated that this could probably be allowed.

Regarding 3D – probably the video and camera parameters could be provided but not depth maps.

Some of the video source material has often been previously compressed – although artifact-reducing pre-processing might be part of a real production environment, we don't normally deal with that in our compression testing, and tend to prefer material that has not been subjected to lossy compression. Also if we want a pre-compressed source, that could presumably be generated by processing source video by such a compression technique rather than obtaining material originally in that form.

It was remarked by various participants that we would probably want material as close as possible to the source after color correction, etc., without application of lossy compression processing – and with as much information provided as possible about the camera, etc.

However, another view was also expressed that it should primarily be desirable to try to get video that matches the typical input for relevant application environments.

It was noted that some of our previous source material such as "Shuttle Start", have had pre-compression applied.

Some viewing of example video material available from TestVid was conducted on Tuesday 27 July at 14:00.

In group discussions, some suggested types of material to collect were as follows:

- It was suggested that obtaining some videoconferencing-style source material is desirable.
- Sports material with high horizontal motion, and high vertical motion was another suggested type of material to collect.
- Material with high chroma intensity.
- High resolution (e.g., HD and Ultra HD) with low noise
- Particularly "difficult" material – like "crowd run" (although that's high noise) or "ducks take off" – not just easy slow motion 8-pixel panning. It was remarked that currently "Basketball Drive" is our toughest HD sequence.
- Artificial test patterns – e.g., mixed with video.
- Progressive scan (not interlaced, not deinterlaced).
- Full 10s (at least) without scene cuts.
- Our test set is mostly from Sony cameras – material from other cameras would be nice.
- Red1 camera material would be nice. (It was remarked that "People on Street" is shot on Red1 – perhaps a somewhat early version of Red1, as it had substantial motion blur.)

Most experts think that usage of uncompressed material is important during standardization.

It was remarked that there may be different desires at the initial development stage of the project versus at a later verification testing stage.

8 TE planning

8.1 General issues for TEs

As a general rule, it was agreed that each TE should be run under the same testing conditions using one software codebase. The general agreed common conditions for experiments were described in the output document JCTVC-B300, as further detailed below.

It is possible to define sub-experiments within particular TEs, eg. TE.xa, TE.xb, etc.

A preliminary TE description is to be approved at the meeting at which the TE plan is established.

A deadline of August 9 was established to express interest in participating in a TE, with finalization of the TE descriptions by August 13 (5 days after the planned availability of TMuC version 0.6).

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.

Those who proposed technology in the respective context (by this or the previous meeting) can propose a TE or TE sub-experiment. Other subjects would not be designated as TEs.

Any technology must have a cross-check partner to establish a TE – 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 TE coordinator to take care of this.

Each participant is required to submit a report – measures will be taken if this principle is violated without good reason.

A summary report by the coordinator is expected to be provided to the subsequent meeting.

Particular TEs planned at this meeting are summarized in the following subsections of this report.

A particularly important TE is TE12, for testing of the individual coding tools in the TMuC.

The TE description for each planned TE is described in an associated output document JCTVC-B3xx for TExx, where "xx" is the TE number.

Good results from a TE 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).

8.2 Common conditions for testing

Common conditions for experiment testing were selected by the group and described in output document JCTVC-B300.

8.3 TE1 Decoder-side Motion Vector Derivation

Continuation of a similar prior TE, coordinated by Mathias Wien (RWTH), summarized as follows:

- Implementation in TMuC
- 6 proposals included
- 2 sub-experiments: Inter prediction, direct mode
- Try to explore interdependency with TMuC tools
- Only high complexity configuration

8.4 TE2 IBDI and memory compression (old TE2)

Continuation of the prior TE on memory compression, coordinated by Takeshi Chujoh (Toshiba), with additional emphasis on:

- Sizes of access units (should be comparable, and idea about the overhead that comes due to overlaps in random access)
- In which parts of the codec is IBDI necessary – only for processing, or also for storage?
- Due to the need for fixed bit rate per access unit, subjective impairments may appear locally -> subjective investigation needed.

- Complexity investigation of different methods
- Is built-in spatial scalability useful e.g. for power saving?

Some discussed aspects:

- Implementation in TMuC
- Use BD rate/PSNR computation interpolation mode 3 (default).
- Also measure the distortion per access block (in order to identify whether there are unusually high distortions locally).

An AHG will study related issues beyond the scope of the TE (e.g. relation with MC etc.).

8.5 TE3 Inter Prediction

This is a continuation of a related prior TE, to be coordinated by Andreas Krutz (TUB).

Sub-experiments will include:

- Warped MC and second order prediction
- Flexible motion partitioning (relation with TE12)
- Multi-hypothesis inter prediction (investigate potentially more efficient methods than with current B picture mechanisms)
- Improved inter prediction with enhanced MC filter (relation with TE12)

8.6 TE4 Variable length coding

This TE will be coordinated by X. Wang (Qualcomm). It is focused on JCTVC-B098 (Qualcomm, Nokia, Tandberg) CBF coding, new interleaving method in large transform blocks

This work needs to wait for new implementation of the VLC coding in the TMuC software.

This is a very focused experiment on potentially improving the VLC entropy coding in the TMuC.

8.7 TE5 TMuC Intra prediction simplification

This TE will be coordinated by T.K. Tan (NTT Docomo). It is focused on investigation of JCTVC-B093 and JCTVC-B118 in a TE (proposing simplifications to be verified for potential adoption by the next meeting).

A question that was raised (not investigated by this TE) was whether the benefit of the "harmonized design" which has 17 prediction directions in case of 4x4 will be tested. It was confirmed that this will be done in TE12 (17 versus 9 directions).

8.8 TE6 Intra prediction improvements

This TE will be coordinated by Ali Tabatabai (Sony). It will include investigation of the following:

- JCTVC-B040 and JCTVC-B042 (bidirectional part) – investigated in a common TMuC environment
- JCTVC-B109 in relation to the method of prediction direction prediction that is already in the TMuC
- JCTVC-B112
- JCTVC-A109 (Mediatek) and JCTVC-A118 (Microsoft)

Tests will be conducted in both the low and high complexity TMuC configurations.

8.9 TE7 Alternative transforms

This TE will be coordinated by Robert Cohen (Mitsubishi). It will include investigation of methods for MDDT simplification: JCTVC-B024, JCTVC-B042 (1DDUT part) JCTVC-B039/JCTVC-B102, and JCTVC-B073, investigated in a common TMuC environment.

Testing will be conducted using high-complexity hierarchical B and all-intra conditions.

8.10 TE8 Parallel entropy coding

This TE will be coordinated by Madhugar Budagavi (TI). It will include investigation of parallel entropy coding technology, including proposals JCTVC-B034, JCTVC-B036, and JCTVC-B088. Two sub-experiments were planned:

- Parallelization of context adaptation (JCTVC-B036, JCTVC-B088).
- Comparing the static part of JCTVC-B034 V2V (without forward adaptation) against the HHI "PIPE" scheme. The JCTVC-B034 mehtod is claimed to have better throughput than PIPE due to the design of its VLC tables.

Specific methods of measuring hardware complexity are planned to be developed in this context.

The validity of such a measure would need to be supported by JCT-VC for taking decisions based on the results.

8.11 TE9 Large block structures

This TE will be coordinated by Munchurl Kim (KAIST). It will test the benefit of large block sizes for various picture sizes as proposed in JCTVC-B028 and JCTVC-B082. Subjective quality investigation should also be included.

Two sub-experiments were planned: Investigation of large block structures and investigation of non-square structures (64x32, 32x16, etc.). In regard to the first of these two areas, coordination with testing to be conducted in TE12 will be needed.

8.12 TE10 In-Loop filtering

This TE will be coordinated by T. Yamakage (Toshiba). It will include the following:

- Subtest 1: De-blocking/De-banding filters (4 methods including proposals from Dresden)
- Subtest 2: Wiener-based in-loop filters (4 methods including proposals from Dresden)
- Subtest 3: Adaptive offset/clipping/rounding (2 methods)

The results will be evaluated according to both objective and subjective performance.

Tests will be conducted under high efficiency hierarchical B, forward-predictive IBBB for all, and additionally Intra-only coding for sub-test 1.

Post processing is not included in this test – this will be studied in related AHG activity.

It was noted that this TE will require a substantial effort, and that subjective viewing needs to be conducted – coordination with Vittorio Baroncini was encouraged.

8.13 TE11 MV coding

This TE will be coordinated by Joel Jung (Orange). It will include investigation of JCTVC-B094, JCTVC-B081, and interleaved MV prediction as proposed by HHI (including comparison of the TMuC

against e.g. simple median prediction). More elements of JCTVC-B094 will also be included (how to generate the reduced set, how to produce the index), and the TE description will be modified to use all inter reference configurations.

Some overlap with TE12 investigations (MV competition, merge vs. skip) seems evident, and coordination was encouraged to minimize duplication of efforts.

Test conditions will likely include high efficiency random access and low complexity low delay configurations. The inter coding conditions (low and high complexity, hierarchical B and IBBB) will be included.

8.14 TE12 Evaluation of TMuC Tools

This TE will be coordinated by Ken McCann (Zetacast). It will include investigation of coding tools currently in the TMuC.

Several other TEs overlap with TE 12. To avoid duplication of efforts, the TE coordinators should take responsibility to coordinate the work of their TEs with the work on TE12.

9 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.

Title and Email Reflector	Chairs	Mtg
JCT-VC project management (jct-vc@lists.rwth-aachen.de) • Coordinate overall JCT-VC interim efforts • Report on project status to JCT-VC reflector • Provide report to next meeting on project coordination status	Gary Sullivan, Jens-Rainer Ohm (co chairs)	N
Test Model under Consideration (TMuC) editing (jct-vc@lists.rwth-aachen.de) • Discuss JCTVC-B205 and perform editorial improvements as appropriate • Produce JCTVC-B204 encoding and tutorial information corresponding to JCTVC-B205	K. McCann (chair), M. Karczewicz, J. Ridge, S. Sekiguchi, T. Wedi, T. Wiegand (vice chairs)	N
Software development and TMuC software technical evaluation (jct-vc@lists.rwth-aachen.de) • Coordinate development of the TMuC software and its distribution to JCTVC members • Produce documentation of software usage for distribution with the software • Deliver TMuC 0.6 and the reference configuration encodings according to JCTVC-B300 for use in common conditions experiments • Complete the integration of the remaining elements of the TMuC design into the software according to the assigned priorities • Improve the configurability of the software	F. Bossen (chair), P. Chen, D. Flynn, W.-J. Han, K. Sühring, H. Schwarz, K. Ugur (vice chairs)	N
Alternative transforms (jct-vc@lists.rwth-aachen.de) • Study the transforms in the TMuC design, including compression performance, computational complexity, dynamic range, storage requirements, etc. • Identify trade-offs of transform characteristics and potential opportunities for simplification of transforms and for reduction in the number of needed transforms • Define and conduct experiments related to using alternative, adaptive, mode-dependent directional, and directional transforms for coding Intra and Inter prediction residuals • Report the results and conclusions of these experiments to the JCT	R. Cohen, R. Joshi (co-chairs)	N

In-loop and post-processing filtering (jct-vc@lists.rwth-aachen.de) • Study enhancement schemes of in-loop filtering, including de-blocking/de-banding/de-noising filters, and adaptive Wiener-based filters including variants with various inputs, combination of filters • Study trade-offs and characteristics of filter designs including complexity and subjective and objective performance • Discuss relationships and evaluation procedures for the filtering techniques • Identify possibilities for harmonization of enhanced in-loop filtering technologies • Study the relationship between in-loop and post-processing filtering	T. Yamakage (chair), Y. J. Chiu, M. Karczewicz, M. Narroschke (vice chairs)	N
Large block structures (jct-vc@lists.rwth-aachen.de) • Study and compare techniques relating to coding block structure • Characterize the trade-offs involved in coding block structure issues, including complexity and compression performance aspects • Identify opportunities for harmonization and simplification of coding block structure	K. Panusopone (chair), M. Budagavi, W.-J. Han, D. He (vice chairs)	N
Memory compression (jct-vc@lists.rwth-aachen.de) • Study memory compression impact on video encoder and decoder: memory bandwidth reduction, graceful power degradation, etc. • Study memory compression schemes including adaptive scaling, DPCM, transform coding, entropy coding, checkerboard sampling, etc.	K. Chono (chair), T. Chujoh, C.S. Lim (vice chairs)	N
Parallel entropy coding (jct-vc@lists.rwth-aachen.de) • Study the merits of various approaches for slice level parallelism • Study PIPE/V2V, parallel context processing, syntax-element partitioning, and other parallelism approaches • Study and develop approaches for hardware and software evaluation of parallel entropy coding at the bin level • Raise and discuss additional issues on parallel entropy coding	M. Budagavi (chair), D. He, A. Segall (vice chairs)	N

Screen content coding (jct-vc@lists.rwth-aachen.de) • 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. • Identify potential needs for action in HEVC standardization	J. Xu, W. Ding (co chairs)	N
Complexity assessment (jct-vc@lists.rwth-aachen.de) • 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. • Identify and recommend tools for algorithmic complexity assessment	D. Alfonso (chair), J. Ridge, X. Wen (vice chairs)	N

10 Output documents produced

The following documents were agreed to be produced as outputs of the meeting. Preliminary versions of the output documents (other than the overall meeting report) were reviewed and approved, and editing periods were authorized for finalization of these documents as described above.

JCTVC-B200 Meeting report of the second meeting of the Joint Collaborative Team on Video Coding (JCT-VC), Geneva, CH, 21-28 July, 2010

JCTVC-B204 Encoder-side description of Test Model under Consideration

JCTVC-B205 Test Model under Consideration

JCTVC-B300 Common test conditions and software reference configurations

JCTVC-B301 Tool Experiment 1: Decoder-Side Motion Vector Derivation

JCTVC-B302 Tool Experiment 2 on IBDI and memory compression

JCTVC-B303 Tool Experiment 3: Inter Prediction in HEVC

JCTVC-B304 Tool Experiment 4: Variable Length Coding

JCTVC-B305 Tool Experiment 5: Simplification of Unified Intra Prediction

JCTVC-B306 Tool Experiment 6: Intra Prediction Improvement

JCTVC-B307 Tool Experiment 7: MDDT Simplification

JCTVC-B308 Tool Experiment 8: Parallel entropy coding

JCTVC-B309 Tool Experiment 9: Large Block Structure

JCTVC-B310 Tool Experiment 10: In-loop filtering

JCTVC-B311 Tool Experiment 11: Motion Vector Coding

JCTVC-B312 Tool Experiment 12: Evaluation of TMuC Tools

11 Planning of next meetings 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 next JCT-VC meeting was planned for October 7th to 15th in Guangzhou, China, under WG 11 auspices.

The ITU was thanked for its excellent hosting of the 2nd meeting of the JCT-VC, and the meeting was closed on 11:40 a.m. on Wednesday, July 28, 2010.

Annex A to JCT-VC report: List of documents

--- Ad hoc group activity reports ---

JCTVC-B001 [G. Sullivan, J.-R. Ohm (chairs)] AHG report: JCT-VC project management

JCTVC-B002 [K. McCann, M. Karczewicz, J. Ridge, S. Sekiguchi, T. Wiegand (chairs)] AHG report: Test Model under Consideration (TMuC) editing

JCTVC-B003 [F. Bossen, P. Chen, D. Flynn, H. Schwarz, K. Ugur (chairs)] AHG report: Software development and TMuC software technical evaluation

JCTVC-B004 [C. Auyeung, S. Lei, K. Sugimoto, H. Yu (chairs)] AHG report: Intra prediction

JCTVC-B005 [R. Cohen, R. Joshi (chairs)] AHG report: Alternative transforms

JCTVC-B006 [B. Jeon, X. Wang, S. Wittmann, T. Suzuki (chairs)] AHG report: MV precision

JCTVC-B007 [T. Yamakage, Y. J. Chiu, M. Narroschke, X. Wang (chairs)] AHG report: In-loop filtering

JCTVC-B008 [K. Panusopone, M. Budagavi, D. He (chairs)] AHG report: Large block structures

JCTVC-B009 [M. Budagavi, A. Segall (chairs)] AHG report: Parallel entropy coding

--- General input contributions ---

JCTVC-B020 [D. Alfonso (STMicro)] Proposals for video coding complexity assessment

JCTVC-B021 [J. Kim, S.-W. Park, J.-Y. Park, B.-M. Jeon (LG)] Intra chroma prediction using inter channel correlation

JCTVC-B022 [S. Park, J. Sung, J. Young Park, B.-M. Jeon] TE3: Motion compensation with adaptive warped reference

JCTVC-B023 [J. Lim, S. Park, B.-M. Jeon (LG)] Extended merging scheme using motion-hypothesis prediction

JCTVC-B024 [C. Yeo, Y. H. Tan, Z. Li, S. Rahardja (I2R)] Mode-dependent fast separable KLT for block-based intra coding

JCTVC-B025 [Y. H. Tan, C. Yeo, Z. Li, S. Rahardja (I2R)] Intra-prediction with adaptive sub-sampling

JCTVC-B026 [S. Klomp, M. Munderloh, J. Ostermann (Leibniz Univ. Hannover)] Decoder-side motion estimation with modified reference list

JCTVC-B027 [K. Iguchi, A. Ichigaya, Y. Shishikui (NHK), S. Sekiguchi, A. Minezawa (Mitsubishi)] Performance report of iterative adjustment intra prediction

JCTVC-B028 [M. Zhou (TI)] Coding efficiency test on large block size transforms in HEVC

JCTVC-B029 [M. Wien (RWTH Aachen Univ.), Y.-J. Chiu (Intel)] Summary Report for TE1 on DMVD

JCTVC-B030 [M. Wien, S. Kamp (RWTH Aachen Univ.)] TE1: RWTH partner report on DMVD

JCTVC-B031 [K. Kazui, J.Koyama, A.Nakagawa (Fujitsu)] Proposal of requirement on very low delay coding

JCTVC-B032 [M. Ueda, S. Fukushima (JVC)] TE1: Refinement Motion Compensation using Decoder-side Motion Estimation

JCTVC-B033 [K. Iwata, S. Mochizuki, R. Hashimoto (Renesas)] Intra prediction based on repetitive pixel replenishment

JCTVC-B034 [G. Korodi, D. He (RIM)] Source selection for V2V entropy coding in HEVC

JCTVC-B035 [X. Yu, D. He, E.-h. Yang (RIM)] Improved quantization for HEVC

JCTVC-B036 [D. He, G. Korodi, G. Martin-Cocher (RIM)] Improved parallelism for V2V entropy coding in HEVC

JCTVC-B037 [S. Lin, M. Yang, J. Zhou, J. Song, D. Wang, H. Yang, J. Fu, H. Yu (Huawei), W. Yue, L. Zhang, S. Ma, W. Gao (Peking Univ.)] TE1: Huawei report on DMVD improvements

JCTVC-B038 [D. Wang, J. Song, H. Yang, M. Yang, H. Yu (Huawei), Xin Zhao, Siwei Ma (Peking Univ.)] Performance improved directional transform techniques

JCTVC-B039 [H. Yang, J, Zhou, H. Yu (Huawei)] Simplified MDDT (SMDDT) for intra prediction residual

JCTVC-B040 [C. Lai, Y. Lin (HiSilicon)] New intra prediction using the correlation between pixels and lines

JCTVC-B041 [X. Zheng (HiSilicon), H. Yu (Huawei)] TE3: Huawei & Hisilicon report on flexible motion partitioning coding

JCTVC-B042 [A. Tanizawa, J. Yamaguchi, T. Shiodera T. Chujoh, T. Yamakage (Toshiba)] Improvement of intra coding by bidirectional Intra Prediction and One-dimensional directional unified transform

JCTVC-B043 [A. Tanizawa, T. Chujoh, T. Yamakage (Toshiba)] Synergistic effect of high accuracy interpolation filter (HAIF) and quad-tree based adaptive loop filter (QALF)

JCTVC-B044 [T. Chujoh, T. Shiodera, T. Yamakage (Toshiba)] TE2: Adaptive scaling for bit depth compression on IBDI

JCTVC-B045 [T. Chujoh, T. Watanabe, T. Yamakage (Toshiba)] Adaptive spatial-temporal prediction of filter coefficients for in-loop filter

JCTVC-B046 [T. Chujoh (Toshiba)] Summary of TE2 on IBDI and memory compression

JCTVC-B047 [Y.-Jen Chiu, L. Xu, W. Zhang, H. Jiang (Intel)] TE1: Fast techniques to improve self derivation of motion estimation

JCTVC-B048 [Y.-Jen Chiu, L. Xu, W. Zhang, H. Jiang (Intel)] TE1: Cross-checking of DMVD result from Huawei

JCTVC-B049 [P. Chen, W. Chien, R. Panchal, M. Karczewicz (Qualcomm)] Geometry motion partition

JCTVC-B050 [B. Lee, M. Kim (KAIST), H. Y. Kim, J. Kim, J. S. Choi (ETRI)] Hierarchical variable block transform

JCTVC-B051 [S. Matsuo, Y. Bandoh, S. Takamura, H. Jozawa (NTT)] Region-based adaptive interpolation filter

JCTVC-B052 [A. Krutz, A. Glantz, T. Sikora (Tech. Univ. Berlin)] TE3: Adaptive global motion temporal prediction

JCTVC-B053 [A. Krutz, T. Sikora (Tech. Univ. Berlin)] Summary report for TE3 on inter prediction in HEVC

JCTVC-B054 [M. Zhou (TI)] Proposed low complexity video encoder settings for HEVC

JCTVC-B055 [K. Senzaki, K. Chono, H. Aoki, J. Tajime, Y. senda (NEC)] BD-PSNR/rate computation tool for five data points

JCTVC-B056 [K. Chono, K. Senzaki, H. Aoki, J. Tajime, Y. senda (NEC)] Performance report of modified conditional joint deblocking-debanding filter

JCTVC-B057 [H. Aoki, K. Chono, K. Senzaki, J. Tajime, Y. senda (NEC)] Performance report of DPCM-based memory compression on TE2

JCTVC-B058 [T. Dove (Testvid)] Video test sequences

JCTVC-B059 [J. Zheng (HiSilicon & Huawei)] Adaptive frequency weighting quantization in macroblock level

JCTVC-B060 [S. Park, B.-M. Jeon (LG)] TE3: cross-check result of JCTVC-B052 adaptive global motion temporal prediction

JCTVC-B061 [Y. Su, A. Segall (Sharp Labs)] Verification of JCTVC-B023 (Extended merging scheme using motion-hypothesis prediction)

JCTVC-B062 [M. Zhou (TI)] Sub-picture based raster scanning coding order for HEVC UHD video coding

JCTVC-B063 [T. Yamamoto, Y. Yasugi (Sharp)] Flexible representation of intra prediction modes

JCTVC-B064 [T. Ikai, T. Yamamoto, Y. Kitaura (Sharp)] A parallel adaptive loop filter

JCTVC-B065 [T. Murakami, K. Sugimoto, S. Sekiguchi, S. Yamagishi, Y. Kato, K. Asai (Mitsubishi)] Consideration on guideline of complexity/performance balance for HEVC test model definition

JCTVC-B066 [S. Sekiguchi, K. Sugimoto, S. Yamagishi, Y. Yamada (Mitsubishi)] Report of Super Hi-Vision coding performance

JCTVC-B067 [S. Sekiguchi, A. Minezawa (Mitsubishi), K. Iguchi, Y. Shishikui (NHK)] DCT-based noise filtering for intra prediction samples

JCTVC-B068 [S. Sekiguchi, Y. Itani (Mitsubishi)] Performance evaluation on implicit direct vector derivation

JCTVC-B069 [S. Sekiguchi, Y. Itani (Mitsubishi)] Report of TE1: Decoder-side motion vector derivation

JCTVC-B070 [K. Sugimoto, S. Sekiguchi, Y. Isu, Y. Itani, A. Minezawa (Mitsubishi)] Proposal on improved entropy coding method for DCT coefficients

JCTVC-B071 [T. Yoshino, S. Naito, S. Sakazawa (KDDI)] Refinement of skip coding mode for HEVC

JCTVC-B072 [Y.-W. Chen, C.-H. Wu, C.-L. Lee, T.-W. Wang, W.-H. Peng (NCTU/ITRI)] MB Mode with joint application of template and block motion compensations

JCTVC-B073 [W. Ding, Y. Shi, B. Yin (Beijing Univ. Tech.)] Fast mode dependent directional transform via butterfly-style transform and integer lifting steps

JCTVC-B074 [M. Karczewicz, H.-C. Chuang, P. Chen, R. Joshi, W.-J. Chien (Qualcomm)] Rounding controls for bidirectional averaging

JCTVC-B075 [J. Yang, K. Won, H. Yang, B. Jeon (SKKU), J. Lim, J. Song (SKT)] In-loop deblocking filtering for intra blocks

JCTVC-B076 [Y.-W. Huang, C.-Y. Chen, C.-W. Hsu, J.-L. Lin, Y.-P. Tsai, J. An, S. Lei (MediaTek)] TE1: Decoder-side motion vector derivation with switchable template matching

JCTVC-B077 [Y.-W. Huang, C.-M. Fu, C.-Y. Chen, C.-Y. Tsai, Y. Gao, J. An, K. Zhang, S. Lei (MediaTek)] In-loop adaptive restoration

JCTVC-B078 [C. Guillemot, T. Poirier (INRIA), and L. Guillo (IRISA/CNRS)] Intra prediction by a linear combination of template matching predictors

JCTVC-B079 [S. Li, L. Yu (Zhejiang Univ.)] Second order prediction

JCTVC-B080 [Y. Chen, L. Yu (Zhejiang Univ.)] Decoder-derived adaptive intra prediction

JCTVC-B081 [K. Sato (Sony)] Proposals for improved MV coding

JCTVC-B082 [K. Sato (Sony)] New large block structure with reduced complexity

JCTVC-B083 [T. Suzuki (Sony)] Study of MC interpolation filter for bi-prediction

JCTVC-B084 [C. Lan, J. Xu, F. Wu, G. J. Sullivan] Screen content coding

JCTVC-B085 [L. Guo, P. Yin, E. Francois (Technicolor)] TE3: Simplified geometry block partitioning

JCTVC-B086 [S. Oh, S. Yea (LG)] TE2: Memory access bandwidth for inter prediction in HEVC

JCTVC-B087 [J. Lou, P. Krit, L. Wang (Motorola)] Performance Evaluation of TMuC

JCTVC-B088 [M. Budagavi, M. U. Demircin (TI)] Parallel context processing techniques for high coding efficiency entropy coding in HEVC

JCTVC-B089 [M. U. Demircin, M. Budagavi, M. Zhou, S. Dikbas (TI)] TE2: Compressed reference frame buffers (CRFB)

JCTVC-B090 [M. Budagavi, M. U. Demircin (TI)] ALF memory compression and IBDI/ALF coding efficiency test results on TMuC-0.1

JCTVC-B091 [H. Zhu (Zhu)] Improvement of arithmetic coding based on probability aggregation

JCTVC-B092 [R. Cohen, A. Vetro, H. Sun (Mitsubishi)] Performance of direction-adaptive residual transforms

JCTVC-B093 [F. Bossen (DOCOMO USA Labs), TK Tan, J. Takiue (NTT DOCOMO)] Simplified angular intra prediction

JCTVC-B094 [F. Bossen, P. Kosse (DOCOMO USA Labs)] Simplified motion vector coding method

JCTVC-B095 [I. S. Chong, W.-J. Chien, N. Malayath, M. Karczewicz (Qualcomm)] Encoder complexity analysis and performance report on adaptive loop filter

JCTVC-B096 [N. Sprljan, S. Paschalakis, P. Wu (Mitsubishi Elect.)] Local intensity compensation for inter prediction in HEVC

JCTVC-B097 [W.-J. Chien, M. Karczewicz, P. Chen (Qualcomm)] TE1: Decoder-side motion vector derivation report from Qualcomm

JCTVC-B098 [M. Karczewicz, P. Chen, W.-J. Chien, X. Wang (Qualcomm)] Variable length coding for coded block flag and large transform

JCTVC-B099 [W.-J. Han (Samsung)] TE1: Verification results of RWTH DMVD approach

JCTVC-B100 [J. H. Min, S. Lee, I. K. Kim, W. J. Han (Samsung), J. Lainema, K. Ugur (Nokia)] Unification of the directional intra prediction methods in TMuC

JCTVC-B101 [G. Clare, J. Jung, S. Pateux (Orange Labs)] Preliminary results on motion vector prediction

JCTVC-B102 [X. Zhao (CAS), L. Zhang, S. Ma, W. Gao (Peking Univ.)] Mode-dependent residual reordering for intra prediction residual (presentation requested 23rd or later)

JCTVC-B103 [C. S. Lim, H. W. Sun, V. Wahadaniah (Panasonic Corp)] Reference frame compression using image coder

JCTVC-B104 [M. Tok, A. Krutz, A. Glantz, T. Sikora (TUB)] Cross-check result of JCTVC-B022 Motion compensation with adaptive warped reference picture

JCTVC-B105 [M. Tok, A. Krutz, A. Glantz, T. Sikora (TUB)] Cross-check result of JCTVC-B032 Refinement motion compensation using decoder-side motion estimation

JCTVC-B106 [Withdrawn] <<withdrawn>>

JCTVC-B107 [C. Auyeung, A. Tabatabai (Sony)] Intra coding with directional DCT and directional DWT

JCTVC-B108 [E. Maani, W. Liu, A. Tabatabai (Sony)] Multi-parameter motion (MPM)

JCTVC-B109 [E. Maani, W. Liu, A. Tabatabai (Sony)] Differential coding of intra modes (DCIM)

JCTVC-B110 [C. Auyeung, A. Tabatabai (Sony)] Separable adaptive loop filter

JCTVC-B111 [K. Misra, J. Zhao, A. Segall (Sharp Labs)] Entropy slices for parallel entropy coding

JCTVC-B112 [J. Zhao, A. Segall (Sharp Labs)] Parallel prediction unit for parallel intra coding

JCTVC-B113 [A. Segall, Y.Su (Sharp Labs)] Codeword restrictions for improved coding efficiency

JCTVC-B114 [Z. Ma, A. Segall (Sharp Labs)] System for graceful power degradation

JCTVC-B115 [Withdrawn] <<withdrawn>>

JCTVC-B116 [M. Karczewicz, R. Panchal, P. Chen (Qualcomm)] TMuC performance evaluation

--- Late registered contributions ---

JCTVC-B117 [P. Tao, D. Li, W. Wu, J. Wen (Tsinghua Univ.)] Intra prediction using localized horizontal spatial prediction

JCTVC-B118 [M. Budagavi (TI)] Angular intra prediction and ADI simplification

JCTVC-B119 [S. Klomp, J. Ostermann (LUH)] Cross-check result of DMVD implementation of MediaTek JCTVC-B076 (late)

--- Break-out activity reports ---

JCTVC-B120 [F. Bossen (BoG)] Report of TMuC design BoG

JCTVC-B121 [R. Sjöberg (BoG)] Report of High-level syntax BoG

--- Additional late contributions ---

JCTVC-B122 [W. Wan (Broadcom), P. Topiwala (FastVdo), P. Pandit (Harmonic), H. Yu (Huawei), Y. Chiu (Intel), B. Jeon (LG), S. Lei (Mediatek), S. Sekiguchi (Mitsubishi), K. Panusopone (Motorola), K. Chono (NEC), Y. Shishikui (NHK), A. Segall (Sharp), M. Zhou (TI), T. Chujoh (Toshiba), T. Suzuki (Sony)] Proposed approach on test model development

--- Additional break-out activity report ---

JCTVC-B123 [F. Bossen (BoG)] BoG report on TMuC software configuration

--- Report output documents ---

JCTVC-B200 Meeting report of the second meeting of the Joint Collaborative Team on Video Coding (JCT-VC), Geneva, CH, 21-28 July, 2010

JCTVC-B204 Encoder-side description of Test Model under Consideration

JCTVC-B205 Test Model under Consideration

JCTVC-B300 Common test conditions and software reference configurations

JCTVC-B301 Tool Experiment 1: Decoder-Side Motion Vector Derivation

JCTVC-B302 Tool Experiment 2 on IBDI and memory compression

JCTVC-B303 Tool Experiment 3: Inter Prediction in HEVC

JCTVC-B304 Tool Experiment 4: Variable Length Coding

JCTVC-B305 Tool Experiment 5: Simplification of Unified Intra Prediction

JCTVC-B306 Tool Experiment 6: Intra Prediction Improvement

JCTVC-B307 Tool Experiment 7: MDDT Simplification

JCTVC-B308 Tool Experiment 8: Parallel entropy coding

JCTVC-B309 Tool Experiment 9: Large Block Structure

JCTVC-B310 Tool Experiment 10: In-loop filtering

JCTVC-B311 Tool Experiment 11: Motion Vector Coding

JCTVC-B312 Tool Experiment 12: Evaluation of TMuC Tools

Annex B to JCT-VC report: List of meeting participants

The participants of the second meeting of the JCT-VC, according to registration desk badge pick-up records collected by the ITU, were as follows:

1. Adolf, Alexander (DVB Project)
2. Alfonso, Daniele (STMicroelectronics)
3. Amon, Peter (Siemens AG)
4. Aoki, Hirofumi (NEC Corporation)
5. Asai, Kohtaro (Mitsubishi Electric Corporation)
6. Auyeung, Cheung (Sony Elenctronics Inc.)
7. Bandoh, Yukihiro (NTT)
8. Barbarien, Joeri (Vrije Universiteit Brussel)
9. Bjøntegaard, Gisle (Tandberg)
10. Bossen, Frank (DOCOMO USA Labs)
11. Botzko, Stephen (Polycom)
12. Budagavi, Madhukar (Texas Instruments Inc)
13. Changcai, Lai (Huawei Technologies Co., Ltd)
14. Chen, Chun-Fu (ITRI International Inc.)
15. Chen, Peisong (Qualcomm Incorporated)
16. Chen, Weizhong (Huawei technologies CO.,LTD)
17. Chen, Ying (Qualcomm)
18. Cheng, Carmen (Hong Kong Applied Science and Technology Research Institute Co. Ltd)
19. Chien, Wei-Jung (Qualcomm Inc.)
20. Chiu, Yi-Jen (Intel Corp.)
21. Choe, Yoonsik (Yonsei University)
22. Choi, Haechul (ETRI)
23. Choi, Hyomin (Kwangwoon University)
24. Choi, Kiho (Hanyang University)
25. Choi, Yungho (Konkuk University)
26. Chono, Keiichi (NEC Corporation)
27. Chujoh, Takeshi (Toshiba Corporation)
28. Coban, Muhammed (Qualcomm)
29. Cohen, Robert (Mitsubishi Electric)
30. Davies, Thomas (BBC Research and Development)
31. De Cock, Jan (Ghent University - IBBT)
32. Ding, Wenpeng (Beijing University Of Technology)
33. Doehla, Stefan (FGFF)
34. Donggyu, Sim (Kwangwoon University)
35. Drugeon, Virginie (Panasonic Corporation)
36. Duenas, Alberto (Cavium Networks)
37. Esche, Marko (Technische Universität Berlin)
38. Fernandes, Felix (Samsung Telecommunications America)
39. Flynn, David (British Broadcasting Corporation)
40. Fogg, Chad (Harmonic)
41. Francois, Edouard (technicolor)
42. Fröjdh, Per (Ericsson AB)
43. Fu, Deliang (Department of Information Science & Electronic Engineering, Zhejiang University, China)
44. Fukushima, Shigeru (JVC KENWOOD Holdings, Inc.)
45. Fuldseth, Arild (Tandberg)
46. Gisquet, Christophe (Canon Inc)
47. Glantz, Alexander (Technische Universität Berlin)
48. Guillo, Laurent (INRIA Rennes Bretagne Atlantique)
49. Gun, Bang (ETRI)
50. Guo, Xun (MediaTek (Beijing) Inc.)
51. Han, Jong-Ki (Sejong University)
52. Han, Woo-Jin (Samsung Electronics)
53. Hang, Hsueh-Ming (Naitonal Chiao Tung University (ITRI-USA))
54. Hattori, Shinobu (Sony Corp)
55. He, Dake (CANADA)
56. He, Yun (Tsinghua Univ.)
57. Henry, Felix (Canon Research Centre France)
58. Hoang, Dzung (Zenverge, Inc.)
59. Hong, Soongi (Yonsei University)
60. Hong, Yingjie (ZTE Corporation)
61. Horowitz, Michael (Vidyo, Inc.)
62. Hsiang, Shih-Ta (Motorola, Inc.)
63. Huang, Yu-Wen (ITRI International Inc.)

64. Ichigaya, Atsuro (NHK)
65. Ishtiaq, Faisal (Motorola Inc.)
66. Jacobs, Marc (Vrije Universiteit Brussel)
67. Jang, Euee S. (Hanyang University)
68. Jang, Euy-Doc (Korea Aerospace University)
69. Jeon, Byeong Moon (LG Electronics)
70. Jeon, Byeungwoo (SKKU)
71. Jeon, Yong-Joon (LG Electronics)
72. Ji, Xiangyang (Tsinghua University)
73. Joshi, Rajan (Qualcomm)
74. Jung, Joel (Orange Labs)
75. Jung, Tae-Young (Hanyang University)
76. Kang, Jung Won (ETRI)
77. Karczewiccz, Marta (Qualcomm Inc.)
78. Karwowski, Damian (Poznan University of Technology)
79. Kazui, Kimihiko (FUJITSU LABORATORIES LTD.)
80. Kazushi, Sato (Sony Corp.)
81. Kenichi, Iwata (Renesas Electronics Corporation)
82. Kim, Hae Kwang (Sejong University)
83. Kim, Heon Joo (Galaxia Communications Co., Ltd.)
84. Kim, Hui Yong (ETRI (Electronics and Telecommunications Research Institute))
85. Kim, Il Koo (Samsung Electronics, Co., Ltd.)
86. Kim, Inkwon (Galaxia Communications Co., Ltd.)
87. Kim, Jae-Gon (Korea Aerospace University)
88. Kim, Munchurl (Korea Advanced Institute of Science and Technology)
89. Kim, Seonghoon (Galaxia Communications Co., Ltd.)
90. Kim, Seongwan (Yonsei University)
91. Klomp, Sven (Leibniz Universität Hannover)
92. Kogure, Takuyo (Panasonic Corporation)
93. Konieczny, Jacek (Poznan University of Technology)
94. Korodi, Gergely (Research in Motion Limited)
95. Koyama, Jumpei (FUJITSU LABORATORIES LTD.)
96. Krutz, Andreas (Technische Universität Berlin)
97. Kuhn, Peter (European Patent Office)
98. Lainema, Jani (Nokia)
99. Lee, Chulhee (KCC/Yonsei University)
100. Lee, Jaeho (Yonsei University)
101. Lee, Jaejoon (Samsung Electronics)
102. Lee, Sangyoun (Yonsei University)
103. Lee, Seok (Samsung Advanced Institute of Technology)
104. Lee, Yung Lyul (Sejong University)
105. Lei, Shawmin (ITRI)
106. Leontaris, Athanasios (Dolby Laboratories, Inc.)
107. Li, Guichun (Huawei Technologies)
108. Li, Junlin (Cisco Systems, Inc.)
109. Li, Shangwen (Department of Information Science & Electronic Engineering, Zhejiang University)
110. Li, Xiang (IENT, RWTH-Aachen University)
111. Lim, Chongsoon (Panasonic Singapore Laboratories)
112. Lim, Jaehyun (LG Electronics)
113. Lim, Jeongyeon (SK Telecom)
114. Lim, Sung-Chang (ETRI)
115. Lin, Jian-Liang (ITRI International Inc.)
116. Lin, Sixin (Huawei Tech Co. Ltd)
117. Liu, Lingzhi (Huawei Technologies)
118. Luthra, Ajay (Motorola)
119. Ma, Siwei (Peking University)
120. Marpe, Detlev (Fraunhofer HHI)
121. Martin-Cocher, Gaëlle (Research In Motion Limited)
122. Matsuo, Shohei (NTT Cyber Space Laboratories, NTT Corporation)
123. Mccann, Ken (ZetaCast representing Samsung)
124. Morin, Luce (INSA de Rennes)
125. Murakami, Tokumichi (Mitsubishi Electric Corporation)
126. Murakami, Tomokazu (Hitachi, Ltd.)
127. Narasimhan, Sam (Motorola)
128. Narroschke, Matthias (Panasonic R&D Center Germany)
129. Neung-Joo, Hwang (Kwangwoon University)
130. Nishi, Takahiro (Panasonic Corporation)
131. Norkin, Andrey (Ericsson AB)
132. Nouira, Chakib (Telnet)
133. Oh, Seung-Kyun (LG Electronics)
134. Ohm, Jens-Rainer (RWTH Aachen University)
135. O'loughlin, Daniel (Research in Motion Ltd)
136. Pandit, Purvin (Harmonic Inc)
137. Pang, Chao (HKUST)
138. Panusopone, Krit (Motorola)
139. Park, Dong-Il (Korea Aerospace University)
140. Park, Jeonghoon (Samsung Electronics Co., Ltd.)
141. Park, Jiho (KETI)
142. Park, Seungwook (LG Electronics)
143. Paschalakis, Stavros (Mitsubishi Electric R&D Centre Europe B.V.)
144. Pateux, Stéphane (Orange Labs)
145. Pauchet, Florelle (Envivio)
146. Pejhan, Sassan (DIRECTV)
147. Peng, Wen-Hsiao (ITRI/NCTU)
148. Peng, Ya-Ti (Intel Corporation)
149. Pereira, Fernando (Instituto Superior Técnico)
150. Poirier, Tangi (INRIA Rennes Bretagne Atlantique)
151. Raad, Mohamad (RaadTech Consulting)
152. Ridge, Justin (Nokia)
153. Sampedro, Jesus (POLYCOM)
154. Sasai, Hisao (Panasonic Corporation)
155. Saunders, Nicholas (Broadcast & Professional Research Labs, Sony Europe Ltd.)
156. Saxena, Ankur (Samsung Telecommunications America)
157. Schwarz, Heiko (Fraunhofer HHI)
158. Segall, Andrew (Sharp Corporation)
159. Sekiguchi, Shun-Ichi (Mitsubishi Electric Corporation)
160. Sharman, Karl (Broadcast & Professional Research Labs, Sony Europe Ltd.)
161. Shen, Bazhong (Broadcom Corp)
162. Shibahara, Youji (Panasonic Corporation)
163. Shima, Masato (Canon Inc.)
164. Shimizu, Shinya (NTT Corporation)
165. Shin, Hwa Seon (KETI (Korea Electronics Technology Institute))
166. Shishikui, Yoshiaki (NHK (Japan Broadcasting Corporation))
167. Sjoberg, Rickard (Ericsson)
168. Sprljan, Nikola (Mitsubishi Electric R&D Centre Europe)
169. Stefanoski, Nikolce (Disney Research, Zurich)
170. Su, Yeping (Sharp Corporation)
171. Suehring, Karsten (Fraunhofer HHI)
172. Sugimoto, Kazuo (Mitsubishi Electric Corporation)
173. Suh, Jung Suk (Samsung Electronics Co., Ltd.)
174. Sullivan, Gary (Microsoft Corp.)
175. Sun, Huifang (Mitsubishi Electric Research Labs)
176. Sung, Jaewon (LG Electronics)
177. Suzuki, Teruhiko (Sony Corp.)
178. Szczuka, Christopher (Broadcom Corporation)
179. Tabatabai, Ali (Sony Electronics)
180. Tan, Thiow Keng (NTT DOCOMO, Inc)
181. Tan, Yih Han (Institute for Infocomm Research)
182. Tanizawa, Akiyuki (TOSHIBA Corporation)
183. Thoma, Herbert (Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V.)
184. Tian, Dong (Technicolor)
185. Tok, Michael (Technische Universität Berlin)
186. Tonomura, Yoshihide (NTT)
187. Topiwala, Pankaj (FastVDO)
188. Ugur, Kemal (Nokia)
189. Vermeirsch, Kenneth (Ghent University -- IBBT)
190. Wan, Wade (Broadcom Corporation)
191. Wang, Dong (ZTE Coporation)
192. Wang, Xianglin (Qualcomm Inc.)
193. Wedi, Thomas (Panasonic)
194. Wen, Xing (HONG KONG UNIV. of SCIENCE & TECHNOLOGY)
195. Wiegand, Thomas (Fraunhofer HHI)
196. Wien, Mathias (RWTH Aachen University)
197. Winken, Martin (Fraunhofer HHI)
198. Won, Kwanghyun (SungKyunKwan University)
199. Wu, Chung-Hao (ITRI)
200. Xiang, Yu (Research in Motion)
201. Xu, Jizheng (Microsoft Corp.)
202. Xu, Kathy (Cisco Systems)
203. Yamakage, Tomoo (TOSHIBA Corporation)
204. Yamamoto, Tomoyuki (SHARP Corporation)

205. Yang, Haitao (Huawei Technologies Co., Ltd.)
206. Yang, Jungyoup (Sungkyunkwan University)
207. Yang, Libo (China Mobile Communications Corporation)
208. Yang, Mingyuan (HUAWEI TECHNOLOGIES CO.,LTD)
209. Yao, Wei (Institute for Infocomm Research)
210. Yea, Sehoon (SAT Grp., DTV Lab., LG Electronics)
211. Yeo, Chuohao (Institute for Infocomm Research)
212. Yonemitsu, Jun (sony co.)
213. Yoshino, Tomonobu (KDDI Corp.)
214. Yu, Haoping (Huawei Technologies (USA))
215. Yu, Lu (Zhejiang University)
216. Zhang, Cixun (Nokia)
217. Zhang, Lei (Broadcom Corporation)
218. Zhang, Li (Peking University)
219. Zheng, Jianhua (Huawei Technologies Co. Ltd)
220. Zheng, Xiaozhen (Huawei Technologies Co., Ltd.)
221. Zhou, Minhua (Texas Instruments Inc)