HEVC 표준화 동향 및 전망
From TMuC to HM-4.0 & WD-4.0

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Organization & requirement of HEVC

• JCT–VC
  – Joint Collaborative Team on Video Coding

• Requirement
  – Development of a standard for video coding technology more advanced (in terms of achievable combinations of compression capability, computational complexity, etc.) than the current AVC standard.
  – Casual goal: 50% coding efficiency than H.264/AVC
    • Same visual quality with half size of bit stream than H.264/AVC
History: Call For Proposals

• 1st JCT–VC meeting at Dresden
  – Evaluation of Joint Call for Proposal (CfP) responses
    • 27 proponents (4 Korean proposals)
  – Results of subjective quality assessment
    • The subjective quality of the proposal encoding was as good, for the best performing proposals, as the quality of the anchors with roughly double the bit rate.
    • A substantial gain can be identified for a prospective starting point of the new generation of video coding standard to be developed in the HEVC initiative.
• **Test Model under Consideration (TMuC)**
  – Combining identified key elements from a group of 7 well-performing proposals.
  – The TMuC is intended to become the basis of a first software implementation.
  – Two elements
    • Document (specification)
    • Software
• **TMuC inside**
  – Framework
    • Coding Unit (Coded Tree Block)/Prediction Unit/Transform Unit
    • Residual quad-tree transform (RQT)
    • Non-square prediction unit partition
      – **Geometry partition (GEO)**, asymmetric motion partition (AMP)
  – Intra prediction
    • Angular intra prediction (ANG)
    • Arbitrary directional intra prediction (ADI)
    • **Edge-based intra prediction**
    • Adaptive intra smoothing (AIS)
    • Planar prediction
    • **Combined intra prediction (CIP)**
  – Transform
    • Large transform (LTR)
    • Rotational transform (ROT)
    • Mode-dependent directional transform (MDDT)
    • Adaptive coefficient scanning for MDDT
• **TMuC inside**
  – Inter prediction / motion
    • Motion vector prediction
      – Advanced motion vector prediction (AMVP)
      – Interleaved motion vector prediction (IMVP)
      – Motion vector competition (MVC)
      – Scaled motion vector (Scaled MV)
    • Merging flag (MRG)
    • Interpolation
      – Switched interpolation filter with offset (SIFO)
      – Directional interpolation filter (DIF)
      – DCT-based interpolation filter (DCT-IF)
      – Maximal Order Minimum Support (MOMS)
    • Adaptive motion vector resolution (AMVRES)
  – Entropy coding
    • Parallel entropy coding for high efficiency (Arithmetic coding)
    • Variable length coding for low complexity (VLC)
  – Loop filter
    • Deblocking filter (DBF)
    • Adaptive loop filter (ALF)
History: HEVC test mode 1.0 (HM-1.0)

- TE12
  - TMuC 내 구현될 CU/PU/TU를 제외한 모든 Tool들 테스트

- TE12 결과에 따라 3th Guangzhou meeting에서 HEVC Test model 결정됨 (HM)
  - JCTVC-C405 Summary of HEVC working draft 1 and HEVC test model (HM)

<table>
<thead>
<tr>
<th>High Efficiency</th>
<th>Low Complexity</th>
</tr>
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<tr>
<td>Coding Unit 8x8 up to 64x64 in tree structure</td>
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<td>Prediction Units</td>
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<td>Transform unit tree (3 level max)</td>
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<td>Transform block size of 4x4 to 32x32 samples</td>
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<td>DCT-based interpolation filter 12 tap</td>
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<td>CABAC entropy coding</td>
<td>LCEC Phase 2</td>
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<td>Internal bit-depth increase (4 bits)</td>
<td>X</td>
</tr>
<tr>
<td>X</td>
<td>Transform precision extension (4 bits)</td>
</tr>
<tr>
<td>Deblocking filter</td>
<td></td>
</tr>
<tr>
<td>Adaptive loop filter</td>
<td>X</td>
</tr>
</tbody>
</table>
Timeline (1)

• Original HEVC timeline
  – Test model selection process begins 2010/04 (1st JCTVC meeting at Dresden, DE)
  – Test model selection by 2010/10 (3rd JCTVC meeting at Guangzhou, CN)
  – Final standard approval by 2012/07 (8th JCTVC meeting at San Jose, US)

• Delayed HEVC timeline (decided at 3rd JCTVC meeting)
  – Test model selection process begins 2010/04 (1st JCTVC meeting at Dresden, DE)
  – Test model selection by 2010/10 (3rd JCTVC meeting at Guangzhou, CN)
  – Committee Draft (CD) approval by 2012/02 (8th JCTVC meeting at San Jose, US)
  – Final Committee Draft (FCD)
  – Draft International Standard (DIS) approval by 2012/07 (10th JCTVC meeting at Stockholm, SE)
  – Final Draft International Standard (FDIS) approval by 2013/01 (12th JCTVC meeting at Gevena, CH)

• With such a timeline being established, only exceptional circumstances should require further delay.
Timeline (2)

• Why the timeline is delayed?
  
  – *We could release the pressure and always go faster if things come together more quickly than anticipated!*
  
  • JCTVC-C023 WG11 **USNB contribution**: HEVC standardization timeline [A. G. Tescher (for USNB to WG11)]
    
    – CD ballot to be issued from the April/May 2012 meeting
    
    – DIS (formerly FCD) ballot to be issued from the October 2012 or January 2013 meeting
    
    – FDIS to be issued from the **July 2013 meeting**.
  
  • It would take 4-5 meeting cycles to come from current TM to CD.
  
  • AVC took 16 meeting cycles from initial H.26L reference to final standard (12 to CD).
  
    – *We should keep the meeting schedule to put sufficient pressure on ourselves!*
  
  • JCTVC-C299 **UK National Body comments** on HEVC Timescales [UKNB to WG11] (late registration, missing prior, available first day)
    
    – Test model selection by 2010/10
    
    – Final standard approval by **2012/07**
  
  • The market is changing rapidly (and new applications are coming), and the timeline should be kept but could be changed later if necessary.
  
  • There is a danger that proprietary codecs may appear and take over if we wait for too long.
Some statistics for historical reference purposes

- **Number of attendance and contributions**
  - 1st meeting (Dresden): 188 people, 40 input documents
  - 2nd meeting (Geneva): 221 people, 120 input documents
  - 3rd meeting (Guangzhou): 244 people, 300 input documents
  - 4th meeting (Daegu): 248 people, 400 input documents
  - 5th meeting (Geneva): 226 people, 500 input documents
  - 6th meeting (Torino): 253 people, 700 input documents
  - 7th meeting (Geneva): ??? people, ???? input documents

- **Will the system collapse since JCTVC document system only supports 3 digit?**
• Subjective test plan for design
  – Plan a subjective test enabling results at the Feb meeting.
  – Plans for subjective testing
    • Preparation of visual comparison for the February meeting will need to be discussed in the next meeting.
    • Initial idea
      – Use a set of rates e.g. as from CfP, and run HM and JM on same conditions. It may not be necessary to run all different constraint cases, RA may be sufficient.
  – Need to prepare JM & HM encodings, roughly as was done for the CfP.
Breakout group

• Breakout group (BoG)의 활성화
  - 급격히 증가한 기고문수로 인해 BoG가 활성화됨
  - 향후에도 이러한 양상을 계속 진행될 듯
  - 16개의 break-out session 진행
    • BoG Report on MV Coding and Parsing Throughput/Robustness
    • Bo BoG report on efficient binary representation of cu_qp_delta syntax for CABAC
    • BoG report on context reduction for CABAC
    • BoG report on CE2: Motion partitioning and OBMC
    • BoG report on quantization offset, adaptive reconstruction level
    • BoG report on unified scans for the significance map and coefficient level coding in high efficiency (JCTVC-F288)
    • BoG report on CAVLC run-level coding
    • BoG report on SDIP throughput
    • BoG Report on CExx: Quantization (Subtest yy: QP coding)
    • CE10: BoG Report
    • Report of the BoG on clean random access (CRA) picture
    • BoG report on simplification of intra_chromaFromLuma mode prediction
    • BoG report on review of deblocking filter related contributions
    • BoG report of CE3 MC interpolation filter
    • BoG report on intra mode coding with fixed number of MPM candidates
    • BoG Report on Screen Content Coding
Mismatch between software (HM) and text (WD)

- **Identify mismatch**
  - JCTVC-F714 High-level syntax mismatches between WD and HM [Q. Shen, Y.-K. Wang (Huawei), K. Sühring (Fraunhofer HHI)]
  - Items
    - Picture order count (POC)
    - Reference picture buffer management
    - Memory Management Control Operations (MMCO) commands
    - Tool on/off flags
• Adoption – related
  – Adoptions are only made under condition that **software** and **WD text** delivery is made in a reasonably timely fashion.
  – Testing should be performed after integration that the tool is really performing its intended purpose and not conflicting with other tools.

• Core experiment (CE) – related
  – CEs should be more focused on testing just a few specific things, and the description should precisely define what is intended to be tested (available by the end of the meeting when the CE plan is approved).
  – Software shared for CE purposes needs to be available with adequate time for study. Software of CEs should be available early, to enable close study by cross-checkers (not just provided shortly before the document upload deadline).
Post-adoption verification activity (1)

• **Background**
  – Potential mismatch between perceived technical content prior to adoption and later integration efforts.
  – Retesting of tools after integration is desirable and the ability to switch off features is a necessary element of that.

• **Request for official verification activity**
  – JCTVC-F465 Samsung and TI
  – Recommendation on a tool experiment similar to TE12 for HM1.0 establishment stage before the current WD moves to committee draft (CD).
    • Partially agreed.
  – 9 processes in HM-3.0 and WD-3.0 are tested as examples
    • 4 processes are determined to be removed in HM-4.0 and WD-4.0
      – Adaptive switching on/off combined coding for CAVLC
      – Direct coding of Intra DC coefficient in CAVLC mode
      – Chroma codeword switch
      – Inferring merge (aka Partial merge)
• Agreed principles
  – Confirmation of intended benefit is to be performed immediately after
    integration of the full set of adoptions from a meeting cycle (which implies
    having the ability to disable each adoption individually).
  – Contributions of things to remove/simplify are to be treated in the same way as
    other proposals.
Entropy Coders: How many do we need in HEVC? (1)

• Current status in HM-4.0 and WD-4.0: 2 separate entropy coders
  – CABAC for High Efficiency
  – CAVLC for Low Complexity

• Problem: Two entropy coding schemes (CABAC & CAVLC) – from F268
  – Increased implementation and verification for product making
  – Increased area and power cost when supporting both entropy coding schemes (like H.264/AVC Baseline and High Profile)
  – Lack of common subset of tools (i.e., lack of complexity scalability) when defining profiles and levels
  – Diverging syntax and higher risk of conformance defects
  – Higher developing effort during standardization phase by maintaining support (more documents!)
Entropy Coders: How many do we need in HEVC? (2)

- **New scalable entropy coder**
  - JCTVC-F268 Unified PIPE-Based Entropy Coding for HEVC (HHI)
  - One Entropy Coding Scheme that can achieve various coding efficiency vs. complexity trade-offs

![Graph showing decoding time relative to HM 3.2 LC anchor (%) and luma BD-rate saving (%)]
Entropy Coders: How many do we need in HEVC? (3)

- **JCTVC-F762 Entropy Coders: How many do we need in HEVC?**
  - K. McCann (Samsung)

- **Architectural View of Entropy Coding**
  - Best architecture is a **single entropy coder**
    - One tool per function unless there is a very good reason to do otherwise
    - Clean standard with no entropy-related interoperability problems
  - Second best is a **scalable entropy coder**
    - Relatively clean standard
    - Manageable interoperability issues (e.g. onion ring profile structure)
  - Third best is to switch between two entropy coders
    - Many decoder ICs will have to implement both entropy coding schemes
      - more complex design than either one alone
      - increased cost of verification testing
    - Less elegant standard
      - Increased risk that application-focused standardisation bodies (e.g. DVB) define their own application-specific profiles
    - More effort required during standardisation work
      - Many more lines of code and more pages of documentation to maintain
Entrophy Coders: How many do we need in HEVC? (4)

- **Suggested way Forward**
  - Agree principle of "only one entropy coder unless there is a very good reason to do otherwise"
  - Agree to determine whether or not there is a very good reason
    - Decision should be based on verifiable facts
  - **Set up a CE** to gather information and perform preliminary analysis to enable decision at next meeting
    - Or could be AHG if the tasks cannot be sufficiently well defined this week
  - After deciding on architecture, then decide on solution

- **Decision of JCTVC**
  - CE for JCTVC-F268
  - New ad-hoc group
    - [AHG9] Entropy Coding Architecture
• Parsing robustness
  – Temporal motion vector prediction case
    • If reference pictures are missing, parser of motion vector prediction will crash.

• Parsing throughput / de-coupling
  – Motion vector coding & intra mode coding
    • Interleaved reconstruction between entropy decoding will decrease parsing throughput

• Solution on motion vector coding
  – JCTVC-F470“Parsing Robustness for Merge/AMVP”(Panasonic)
    • Use **fixed list length of Merge/AMVP candidates** to decouple Merge/AMVP candidate list derivation and Merge/AMVP indices parsing.
    • **Additional Merge/AMVP candidates** are assigned to the empty positions in the list
    • 0.1% BR saving for HE and 0.3% BR saving in the RA scenarios, and 0.2% BR saving for HE and 0.7% BR saving for LC on average in the LD
• Solution on intra mode coding
  – JCTVC-F378, Intra mode parsing without access neighbouring information (Samsung)
  – 2MPM
    • If only one MPM is available and the MPM is not equal to planar mode, **insert planar mode** as the second MPM mode
    • If only one MPM is available and the MPM is equal to planar mode, **insert DC mode** as the second MPM mode
  – Separate DC and planar mode, DC and planar are coded as ordinary mode
    • Mode order: Planar, Ver, Hor, DC, ......
  – Fixed intra chroma mode number (6 modes), no chroma mode pruning
    • **Total 6 modes** is used as HM3.0 : DM, LM, first 4 Luma modes
      • If DM is one of the first 4 modes, the related mode is replaced by **right-down diagonal mode**
  – Disable neighboring dependency of context modeling for chroma mode coding

<table>
<thead>
<tr>
<th>First MPM intra direction</th>
<th>Second MPM assignment</th>
<th>Variant 1</th>
<th>Variant 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 VER</td>
<td>2 DC</td>
<td>3 Planar</td>
<td></td>
</tr>
<tr>
<td>1 HOR</td>
<td>2 DC</td>
<td>3 Planar</td>
<td></td>
</tr>
<tr>
<td>2 DC</td>
<td>3 Planar</td>
<td>2 Planar</td>
<td></td>
</tr>
<tr>
<td>3 Planar</td>
<td>2 DC</td>
<td>3 DC</td>
<td></td>
</tr>
<tr>
<td>4..34 Angular modes</td>
<td>2 DC</td>
<td>3 Planar</td>
<td></td>
</tr>
</tbody>
</table>
Rate calculation in HM reference software

• Bitrate calculation
  – Confusion about the bitrates reported by the encoder before HM-3.1
    • They do not match the bitrate that can be derived based on the file size of the bitstream.
    • Reported bit rate does not include SEI messages.
  – After HM-3.1: the encoder now outputs two rates
    • A: parameters sets + coded slices (without Annex B and SEI messages)
      – Bitrate based on byte counts for all NAL units except SEI and AU NAL units (this is slightly different from what is currently done as startcodes and possibly other bytes related to the use of Annex B would not be counted)
    • B: all data written to the bitstream file
    • Bitrate A would be the one used for BD-rate computations.
  – Bit count of HM-3.1 and later may not be exactly comparable as start codes are not counted.
Screen content coding

- Screen content coding (SCC)
  - At 4th Daegu meeting
    - After discussion, it was agreed that screen content is considered within the HEVC scope, but it should not become a major focus in the work, must not cause a schedule delay, and must not put complex features in "mainstream" profile(s) that are only for that purpose.
  - New common test condition for SCC
    - Class F: 4 additional SCC sequences are approved.
    - Available at ftp://hevc@ftp.tnt.uni-hannover.de/testsequences
      - BasketballDrillText_832x480_50.zip
      - ChinaSpeed_1024x768_30.zip
      - SlideEditing_1280x720_30.zip
      - SlideShow_1280x720_20.zip
      - For detailed descriptions, please see F771
### High level description of HM-4.0

<table>
<thead>
<tr>
<th>High Efficiency Configuration</th>
<th>Low Complexity Configuration</th>
</tr>
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<td>Coding Unit (CU) tree structure (8x8 up to 64x64 luma samples)</td>
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<td>Prediction Units (PU)</td>
<td></td>
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<tr>
<td><strong>Asymmetric Motion Partition (AMP)</strong></td>
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<tr>
<td>Transform unit tree structure (RQT) (3 level max.)</td>
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<tr>
<td>Transform block size of 4x4 to 32x32 samples (core will be determined)</td>
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<tr>
<td><strong>Mode-dependent Transform for 4x4 block (DST)</strong></td>
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<tr>
<td><strong>Non-square Quad-tree Transform (NSQT)</strong></td>
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<tr>
<td>Spatial Intra Prediction (up to 34 angular directions and <strong>Planar</strong>)</td>
<td>Adaptive Intra Smoothing</td>
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<td><strong>Intra Chroma Prediction using Luma samples</strong></td>
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<td>DCT-based interpolation filter for luma samples (1/4-sample, 8-tap)</td>
<td>DCT-based interpolation filter for chroma samples (1/8-sample, 4-tap)</td>
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<tr>
<td><strong>Coding Unit based Skip &amp; Prediction Unit based merging</strong></td>
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<tr>
<td>Advanced motion vector prediction (AMVP)</td>
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<tr>
<td>Context adaptive binary arithmetic entropy coding (CABAC)</td>
<td>Context adaptive VLC (CAVLC)</td>
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<tr>
<td>Deblocking filter</td>
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<tr>
<td><strong>Sample Adaptive Offset (SAO)</strong></td>
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<tr>
<td>Adaptive loop filter (ALF)</td>
<td>X</td>
</tr>
<tr>
<td>Category</td>
<td>Coding tool</td>
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<tr>
<td>structure</td>
<td>Basic block</td>
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<td>structure</td>
<td>Quad-tree depth</td>
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<tr>
<td>structure</td>
<td>Quad-tree representation</td>
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<td>structure</td>
<td>Motion partition shape</td>
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<td>structure</td>
<td>Transform representation</td>
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<td>structure</td>
<td>Transform shape</td>
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<tr>
<td>structure</td>
<td>Relationship between prediction and transform</td>
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<td>Number of directions (luma)</td>
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<tr>
<td>Intra</td>
<td>Number of directions (chroma)</td>
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<tr>
<td>Intra</td>
<td>Context pixel smoothing</td>
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<tr>
<td>Intra</td>
<td>Context pixel Interpolation</td>
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### HEVC 표준화 동향 및 전망

**H.264/AVC vs HM-4.0 (high level) – (2)**

<table>
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<th>Category</th>
<th>Coding tool</th>
<th>H.264/AVC</th>
<th>HEVC</th>
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<tr>
<td>Transform</td>
<td>Additional transform</td>
<td>-</td>
<td>4x4 DST</td>
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<tr>
<td>Inter</td>
<td>Motion vector prediction</td>
<td>Median (implicit)</td>
<td>Multiple candidates</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(explicit signaling)</td>
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<tr>
<td>Inter</td>
<td>Motion vector coding &amp; residual coding</td>
<td>Direct</td>
<td>PU-based merging</td>
</tr>
<tr>
<td>Interpolation</td>
<td>Luma</td>
<td>6 tap + bi-linear</td>
<td>8 tap</td>
</tr>
<tr>
<td>Interpolation</td>
<td>Chroma</td>
<td>Bi-linear</td>
<td>4 tap</td>
</tr>
<tr>
<td>Interpolation</td>
<td>Filtering structure</td>
<td>Cascaded filtering for</td>
<td>Direct filtering only</td>
</tr>
<tr>
<td></td>
<td></td>
<td>quarter-pel (6 tap + bi)</td>
<td></td>
</tr>
<tr>
<td>Entropy</td>
<td>High efficiency entropy coding</td>
<td>CABAC</td>
<td>CABAC</td>
</tr>
<tr>
<td>Entropy</td>
<td>Low complexity entropy coding</td>
<td>(CA)VLC</td>
<td>(CA) VLC</td>
</tr>
<tr>
<td>In-loop filter</td>
<td>Deblocking filter unit</td>
<td>4x4, 8x8</td>
<td>8x8 only</td>
</tr>
<tr>
<td>In-loop filter</td>
<td>Sample adaptive offset</td>
<td>-</td>
<td>Edge offset, Band offset</td>
</tr>
<tr>
<td>In-loop filter</td>
<td>Adaptive loop filter</td>
<td>-</td>
<td>16 filters, 3 filter shapes (5x5, 7x7, 9x9), CU-synchronized</td>
</tr>
</tbody>
</table>

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Every JCTVC meeting usually produce following documents (Torino example)

- HEVC Reference Software Manual
  - JCTVC-F634 HEVC Reference Software Manual
- Software guidelines for the HEVC reference software
  - JCTVC-F688 Software guidelines for the HEVC reference software
- Meeting report from JCT-VC chair
  - JCTVC-F800 Meeting report of the sixth meeting of the Joint Collaborative Team on Video Coding (JCT-VC), Torino, IT, 14-22 July 2011
    - Until Torino meeting, official meeting reports were uploaded in ftp only
- Test model description (informative)
  - JCTVC-F802 HM4: HEVC Test Model 4 Encoder Description
- Working draft (normative)
  - JCTVC-F803 WD4: Working Draft 4 of High-Efficiency Video Coding
- Common test conditions and software reference configurations
  - JCTVC-F900 Common test conditions and software reference configurations
Useful information (1)

• JCTVC Document management system
  – http://phenix.int-evry.fr/jct/

• HM source code version control (SVN)
  – https://hevc.hhi.fraunhofer.de/svn/svn_HEVCSoftware/
  – svn://hevc.kw.bbc.co.uk/svn/jctvc-jm

• JCTVC HM Track
  – JCTVC issue & bug tracker
  – bug reports (ticket)
  – source navigation 가능
Useful information (2)

• Meeting note of each JCTVC meeting
  – 채택기술 및 각 미팅의 모든 결정사항들이 정리되어 있음
  – JCTVC-F800 Meeting report of the sixth meeting of the Joint Collaborative Team on Video Coding (JCT-VC), Torino, IT, 14-22 July 2011
  – Document management system에 등록되지 않은 meeting note들은 아래의 ftp site에 존재
    • http://wftp3.itu.int/av-arch/jctvc-site/
    • 참고적으로 document management system 이 완성되기 전 3회 광저우 미팅까지의 모든 기고문들도 이 곳에서 찾을 수 있음
Remaining jobs

• Technical stabilization and finalization
  – HM description
  – WD text

• Profiling
  – High efficiency profile (?)
  – Low complexity profile (?)

• Scalable and Multi-view extension of HEVC
Conclusions & Questions

- HEVC is evolving and toward to CD
- CD will be issued at 8th JCTVC meeting
- FDIS is schedule in Jan. 2013

- Any questions?
- Or feel free to contact with e-mail: ilkoo.kim@samsung.com
- Thank you!