The Arrival of the High Efficiency Video Coding Standard (HEVC)

(Rec. ITU-T H.265 | ISO/IEC 23008-2 | MPEG-H Part 2)

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Presentation for *Data Compression Conference (DCC 2013)*

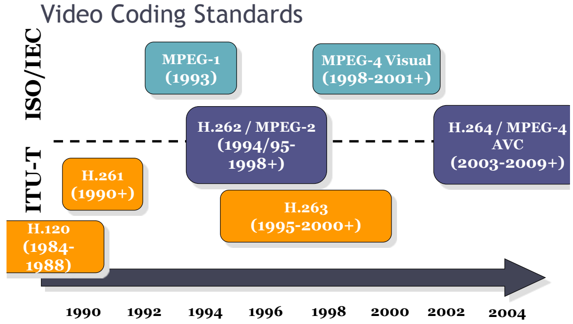
H.264/MPEG-4 Advanced Video Coding (AVC): The basic idea (2003)

- Compress digital video content
- Twice as much as you did before
- With the same video quality, e.g. as MPEG-2 or H.263
- Or get higher quality with the same number of bits (or a combo)
- Example: higher quality may mean higher resolution, e.g. HD
- And better adaptation to applications and network environments
- Unfortunately, with substantially higher computing requirements and memory requirements for both encoders and decoders

High Efficiency Video Coding (HEVC): The basic idea (2013)

- Compress digital video content
- Twice as much as you did before
- With the same video quality, e.g. as AVC
- Or get higher quality with the same number of bits (or a combo)
- Example: higher quality may mean higher resolution, e.g. Ultra-HD
- And better adaptation to applications and network environments
- Unfortunately, with substantially higher computing requirements and memory requirements for both encoders and decoders
  - But this time the decoder is not so tough (~1.5x)
  - And the memory increase is not so much
  - And the parallelism opportunities are better (throughput)

Chronology of International Video Coding Standards

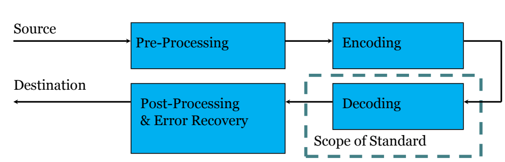


Video Coding Standards Organizations

- **ISO/IEC MPEG** = "**Moving Picture Experts Group**" (ISO/IEC JTC 1/SC 29/WG 11 = International Standardization Organization and International Electrotechnical Commission, Joint Technical Committee 1, Subcommittee 29, Working Group 11)
- **ITU-T VCEG** = "**Video Coding Experts Group**" (ITU-T SG16/Q6 = International Telecommunications Union – Telecommunications Standardization Sector (ITU-T, a United Nations Organization, formerly CCITT), Study Group 16, Working Party 3, Question 6)
- **JVT** = "**Joint Video Team**" collaborative team of MPEG & VCEG
- **SMPTE (Society of Motion Picture and Television Engineers)**
- **New**: **JCT-VC** = "**Joint Collaborative Team on Video Coding**" team of MPEG & VCEG, continuing the collaborative relationship for a new project (established January 2010)
- **New**: **JCT-3V** = "**Joint Collaborative Team on 3D Video**" extension development team of MPEG & VCEG for 3D (est. May 2012)

The *Scope* of Video Coding Standardization

- Only the *Syntax* and *Decoder* are standardized:
  - Permits optimization beyond the obvious
  - Permits complexity reduction for implementability
  - Provides some capability, but *no guarantee* of Quality



HEVC and the JCT-VC Partnership

- Initial groundwork in VCEG and MPEG
  - "Key Technical Area" (KTA) study and software in VCEG
  - "Call for Evidence" in MPEG
- Agreement in January 2010 to form new team VCEG-AM90 / N11112
- **Joint Call for Proposals** on Video Coding Technology issued January 2010 VCEG-AM91 / WG 11 N11113
- **Joint Collaborative Team (JCT) on Video Coding (JCT-VC)**
- Chairs: Gary Sullivan (Microsoft)
  & Jens-Rainer Ohm (RWTH Aachen Univ.)
- Project name **High Efficiency Video Coding (HEVC)** agreed April 2010
- Formal classifications **Rec. ITU-T H.265** & **ISO/IEC 23008-2**
- Document archives and software are publicly accessible
  - http://hevc.info **(general info site with links & papers, maintained by HHI)**
  - http://jct-vc.org (http://www.itu.int/ITU-T/studygroups/com16/jct-vc/index.html)
  - http://phenix.it-sudparis.eu/jct
  - http://ftp3.itu.ch/av-arch/jctvc-site
- Email reflector
  - http://mailman.rwth-aachen.de/mailman/listinfo/jct-vc

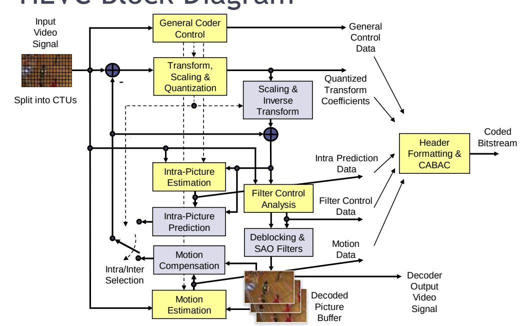
JCT-VC Meetings & Milestones

- First "A" meeting: Dresden, Germany, 15-23 Apr. 2010
  - **188 people, 40 input documents,** ***first Test Model under Consideration (TMuC)***
- Second "B" meeting: Geneva, Switzerland 21-28 July 2010
  - **221 people, 120 input documents**
- Third "C" meeting: Guangzhou, China, 7-15 Oct. 2010
  - **244 people, 300 input documents ,** ***first Working Draft and test model (HM 1)***
- Fourth "D" meeting: Daegu, Korea, 20-28 Jan. 2011
  - **248 people, 400 input documents**
- Fifth "E" meeting: Geneva, Switzerland, 16-23 Mar. 2011
  - **226 people, 500 input documents**
- Sixth "F" meeting: Turin, Italy, 14-22 July 2011
  - **253 people, 700 input documents**
- Seventh "G" meeting: Geneva, Switzerland, 21-30 Nov. 2011
  - **284 people, 1000 input documents**
- **Eighth "H" meeting: San José, United States, 1-10 Feb. 2012**
  - **255 people, 700 input documents,** ***ISO/IEC CD – Draft 6***
- Ninth "I" meeting: Geneva, Switzerland 30 Apr. – 8 May 2012
  - **241 people, 550 input documents**
- **Tenth "J" meeting: Stockholm, Sweden, 11-20 July 2012**
  - **214 people, 550 input documents** (call for proposals on scalability), ***ISO/IEC DIS – Draft 8***
- Eleventh "K" meeting: Shanghai, China 10-19 Oct. 2012
  - **235 people, 350 input documents** (new work on scalability begun)
- **Twelfth "L" meeting: Geneva, Switzerland, 16-23 Jan. 2013,** ***ISO/IEC FDIS 23008-2 & ITU-T Consent H.265 – Draft 10***
  - **262 people, 450 input documents**

Basic Technology Architecture

- All proposals were basically conceptually similar to AVC (and prior standards)
  - Block-based
  - Variable block sizes
  - Block motion compensation
  - Fractional-pel motion vectors
  - Spatial intra prediction
  - Spatial transform of residual difference
  - Integer-based transform designs
  - Arithmetic or VLC-based entropy coding
  - In-loop filtering to form final decoded picture
- Lots of variations at the individual "tool" level
- Proposal survey output documents:
  - Decoder speed JCTVC-A201
  - Architectural outline JCTVC-A202
  - Table of design elements JCTVC-A203

HEVC Block Diagram



Technology Design Elements (part 1)

High-level Structure
Enhanced support for frame rate temporal sub-layer nesting and open-GOP random access
Tile-structured rectangular region coding
Wavefront-structured dependencies for parallelism
Enhanced reference picture set syntax
Segmentation Units and Blocks
Coding tree units (CTUs) are the fundamental region units roughly analogous to macroblocks; CTU size can be 16×16, 32×32 or 64×64 luma samples (with corresponding chroma)
Coding units (CUs) quadtree structure (square coding unit block sizes 2N×2N, for N=4, 8, 16, 32; Intra-picture vs. Inter-picture prediction selected at the CU level
Prediction units (PUs) for coding unit size 2N×2N: for Inter, 2N×2N, 2N×N, N×2N, N×N and, for 2N>8, also 2N×(N/2+3N/2) and (N/2+3N/2)×2N; for Intra, only 2N×2N and N×N (N×N only when 2N×2N is the minimum CU size)
Transform units (TUs) quadtree structure within coding unit
Spatial Signal Transformation, Transform skip, Lossless and PCM Representation
Transform blocks (TBs) of 4×4, 8×8, 16×16 or 32×32 samples (always square)
DCT-like integer block transform; for luma Intra 4×4 also a DST-based integer block transform
Transforms can cross prediction unit boundaries for Inter; not for Intra
Transform can be skipped for 4×4 blocks
Also a predictive lossless coding mode with both the transform and quantization skipped
PCM coding with worst-case bit usage limit

Technology Design Elements (part 2)

Intra-picture Prediction
Angular intra prediction (33 directions with unified processing and prediction filtering)
"DC" average prediction
Planar surface fitting prediction
Inter-picture Prediction
Luma motion compensation interpolation: 1/4 sample precision, 7 or 8 tap separable with 7 bit tap values
Chroma motion compensation interpolation: 1/8 sample precision, 4×4 separable with 6 bit tap values
Advanced motion vector prediction with motion vector "competition" and temporal candidate
Region merging prediction (spatially and temporally) and direct and skip modes
No inter prediction for 4×4, No bi-prediction smaller than 8×8
Entropy Coding & Transform Coefficient Coding
Context adaptive binary arithmetic coding (CABAC) – enhanced and simplified
Transform coefficients for large transform blocks are handled in 4×4 transform coefficient groups
Mode-dependent selection among three 4×4 scan orders: diagonal, horizontal and vertical
A sign bit can be "hidden" in the parity of each active 4×4 transform coefficient group
In-Loop Filtering
Deblocking filter (parallel-friendly, for 8×8 edges only)
Sample-adaptive offset filter with contouring band smoothing and directional edge refinement effects

HEVC – High-layer syntax structure

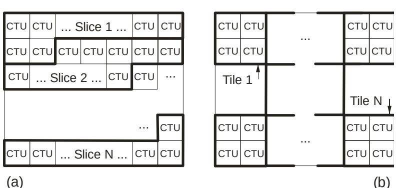
- NAL unit structuring:
  - Similar concept as in AVC – identification of VCL payload & parameter sets
  - More NAL unit types (64 max.), currently 25 defined, 2 byte header
  - New *video parameter set* describing bitstream characteristics
- Enhanced support for open-GOP random access and bitstream splicing
  - Specific VCL payload types: Clean random access (CRA), broken link access (BLA), with random access decodable (RADL) and random access skipped (RASL) leading pictures
- Support for temporal sub-layers
  - Temporal sub-layer access (TSA) allows to identify at which points of the bitstream a change in picture rate can be made
- Reference picture set syntax
  - More explicit and robust than in AVC

HEVC – Slices, Slice Segments, Tiles, and Wavefronts

- A ***slice*** is an independently decodable entity; one picture can contain multiple slices
  - Significant number of parameters conveyed in slice header
  - A slice is often restricted by packet payload size, and therefore consists of variable number of CTUs
  - Can chop into *slice segment* strings of CTUs for packetization
- ***Tiles*** are also independently decodable in terms of entropy coding and intra prediction, but have a lean header, and share information from the picture level
  - Dividing a picture into regular-sized tiles (fixed number of CTUs), enables efficient parallel processing and provides entry points for local access
- Ordered substreams for ***wavefront parallel processing*** of CTUs that are mutually independent w.r.t. CABAC adaptation

HEVC – Slices and Tiles

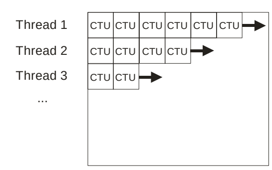
- Typical examples of slice (a) and tile (b) partitioning of a picture



- Slice and tile partitioning are only allowed at the granularity of CTUs (CU level partitioning was possible but complicated)

Wavefront Parallel Processing

- Wavefront processing allows to run several processing threads in a slice over rows of CTUs with a 2-CTU delay that allows adaptation



Profiles, Tiers, and Levels

- As in previous standards, HEVC will define conformance points by **profile** (combinations of coding tools) and **levels** (picture sizes, maximum bit rates etc.).
- New concept of "**tiers**" for bit rate and buffering capability
- A conforming bitstream must be decodable by any decoder that is conforming the given profile/tier/level combination
- **3 profiles** in the first version (see next slide)
- **13 levels** which cover all important picture sizes ranging from VGA at low end **up to 8K x 4K** at high end

  (Level 5.1 includes 4k Ultra HD @60 Hz, Level 6.1 includes 8k @60)
- Most levels have **two tiers: High** and **Main**

HEVC Profiles

- **"Main" profile** approximately follows the overview given in the preceding slides, with following restrictions
  - Only 8-bit video with YCbCr 4:2:0 is supported
  - Wavefront processing can only be used when multiple tiles in a picture are not used
- **"Main Still Picture" profile**
  - For still-image coding applications
  - Bitstream contains only a single (intra) picture
  - Includes all (intra) coding features of Main profile
- **"Main 10" profile**
  - Additionally supports up to 10 bits per sample
  - Includes all coding features of Main profile

HEVC Levels and Tiers

Level	Max luma sample rate MaxLumaSR (samples/sec)	Max luma picture size MaxLumaPS (samples)	Max bit rate MaxBR (1000 bits/s)		Max CPB size MaxCPB (1000 bits)		Min Compression Ratio MinCR	Max slices per picture MaxSlicesPerPicture	Max # of tile rows MaxTileRows	Max # of tile columns MaxTileCols
			Main tier	High tier	Main tier	High tier				
1	552 960	36 864	128	-	350	-	2	16	1	1
2	3 686 400	122 880	1 500	-	1 500	-	2	16	1	1
2.1	7 372 800	245 760	3 000	-	3 000	-	2	20	1	1
3	16 588 800	552 960	6 000	-	6 000	-	2	30	2	2
3.1	33 177 600	983 040	10 000	-	10 000	-	2	40	3	3
4	66 846 720	2 228 224	12 000	30 000	12 000	30 000	4	75	5	5
4.1	133 693 440	2 228 224	20 000	50 000	20 000	50 000	4	75	5	5
5	267 386 880	8 912 896	25 000	100 000	25 000	100 000	6	200	11	10
5.1	534 773 760	8 912 896	40 000	160 000	40 000	160 000	8	200	11	10
5.2	1 069 547 520	8 912 896	60 000	240 000	60 000	240 000	8	200	11	10
6	1 069 547 520	35 651 584	60 000	240 000	60 000	240 000	8	600	22	20
6.1	2 139 095 040	35 651 584	120 000	480 000	120 000	480 000	8	600	22	20
6.2	4 278 190 080	35 651 584	240 000	800 000	240 000	800 000	6	600	22	20

HEVC HM 5 **PSNR** Performance

- **HEVC HM 5.0 High Efficiency** vs. **JM 18.2 AVC High Profile** (ITU-T H.264 | ISO/IEC 14496-10)
- Source: **JCTVC-H0360** by **B. Li, G. J. Sullivan, and J. Xu** (Jan '12)
- **Subjective quality** is what really matters, but here are some PSNR results

Video Sequence Class	HM 5.0 HE Bit Rate Savings for Equal PSNR		
	All Intra	Random Access	Low Delay
A (3k x 2k & 4k x 2k @ 30)	24%	33%	
B (1920 x 1080 HD @ 24)	24%	42%	47%
C (832 x 480 WVGA @ 30 & 60)	22%	33%	40%
D (416 x 240 WQVGA @ 30 & 60)	18%	31%	37%
E (1280 x 720 HD @ 60)	27%		50%
Average	**23%**	**36%**	**43%**
Average Encoding Time	94%	139%	212%
Average Decoding Time	136%	46%	81%

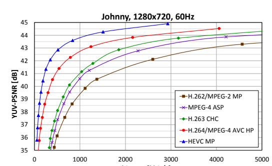
- We're generally doing *better* in subjective quality than PSNR
- Note that HEVC does better for higher video resolution (and low delay use)
- Other caveats also apply; however, we compensated for many non-normative issues: combined luma/chroma PSNR, latest Bjøntegaard delta interpolation method, reference picture lists construction, QP settings, etc.
- These test results are *not* officially endorsed by JCT-VC or others

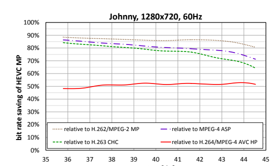
HEVC HM 8 PSNR Performance

- **HEVC HM 8** with "Main Profile" settings vs. various previous standards which used similar encoder optimization, GOP structure setting etc. (data on following slides kindly provided by Heiko Schwarz – see ***IEEE Trans. CSVT*** paper Dec. 2012)
- Various configuration settings with appropriate constraints (low delay, random access) are included
  - Note that HEVC does better for lower bit rates and higher video resolution (and low delay use)
- Another contribution (**JCTVC-I0407**) reported results for 18 test sequences 1080p@60fps (from test set recently recommended in ITU-R report BT.2245), comparing HM6 MP vs. AVC HP:
  - 21% average bit rate savings for all-Intra
  - 36% average bit rate savings for random access
  - 43% average bit rate savings for low delay

HEVC HM 8 PSNR Performance

- Interactive application (low delay)



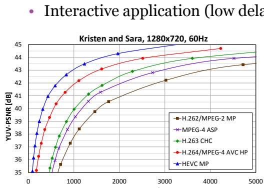


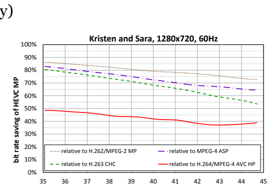
Average over entire test set and all bit rates:

Encoding	Bit rate savings relative to:			
	H.264 / MPEG-4 AVC HP	H.263 CHC	MPEG-4 ASP	H.262 / MPEG-2 MP
HEVC MP	40.3 %	67.9 %	72.3 %	80.1 %
H.264/MPEG-4 AVC HP	–	46.8 %	54.1 %	67.0 %
H.263 CHC	–	–	13.2 %	37.4 %
MPEG-4 ASP	–	–	–	27.8 %

HEVC HM 8 PSNR Performance

- Interactive application (low delay)





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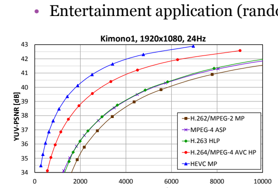
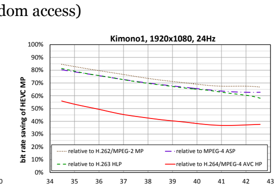
H.264/MPEG-4 AVC HP	–	46.8 %	54.1 %	67.0 %
H.263 CHC	–	–	13.2 %	37.4 %
MPEG-4 ASP	–	–	–	27.8 %

HEVC HM 8 PSNR Performance

- Entertainment application (random access)



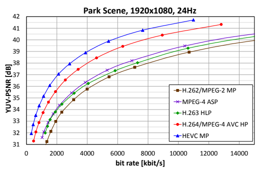


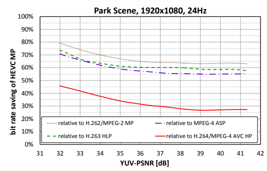
Average over entire test set and all bit rates:

Encoding	Bit rate savings relative to:			
	H.264 / MPEG-4 AVC HP	MPEG-4 ASP	H.263 HLP	H.262 / MPEG-2 MP
HEVC MP	35.4 %	63.7 %	65.1 %	70.8 %
H.264/MPEG-4 AVC HP	–	44.5 %	46.6 %	55.4 %
MPEG-4 ASP	–	–	3.9 %	19.7 %
H.263 HLP	–	–	–	16.2 %

HEVC HM 8 PSNR Performance

- Entertainment application (random access)





Average over entire test set and all bit rates:

Encoding	Bit rate savings relative to:			
	H.264 / MPEG-4 AVC HP	MPEG-4 ASP	H.263 HLP	H.262 / MPEG-2 MP
HEVC MP	35.4 %	63.7 %	65.1 %	70.8 %
H.264/MPEG-4 AVC HP	–	44.5 %	46.6 %	55.4 %
MPEG-4 ASP	–	–	3.9 %	19.7 %
H.263 HLP	–	–	–	16.2 %

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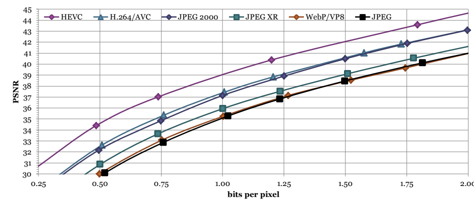
HEVC HM 6 PSNR Performance: Intra only

- Image "Barbara"

Source: **Nguyen/Marpe (JCTVC-I0595)**



- Kodak test set: Bit rate savings of HEVC intra vs. other codecs

Anchor →	H.264/AVC	JPEG 2000	JPEG XR	WebP	JPEG
HEVC	15.9	22.9	30.4	31.4	43.3

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HM5 vs AVC Subjective Performance

- **HEVC HM 5** vs. AVC JM18 which used similar encoder optimization, same GOP structure setting etc. (following results from committee report **JCTVC-H1004**)
- **Subjective quality is what really matters**; PSNR is not able to reflect that HEVC provides better spatio-temporal consistency of the decoded video with less fluctuating artifacts - e.g. due to the larger block structures, new loop processing elements and better interpolation filters
- Emphasis in this test on delay-tolerant applications with relatively frequent random access points
- DSIS methodology was used, 9 test sequences at 4 rates each, 24 test subjects were employed in front of a full HD display at 2H viewing distance
- These test results indicate that for relevant cases a 50% or more bit rate reduction is achieved compared to AVC High Profile

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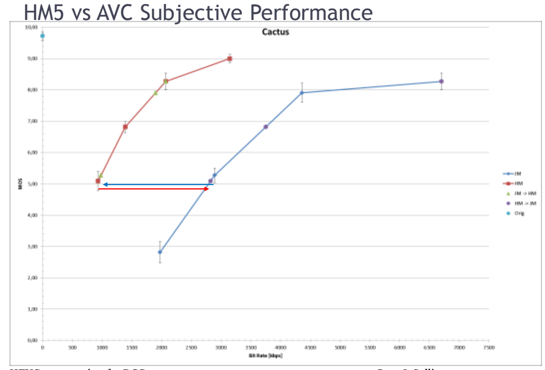
HM5 vs AVC Subjective Performance



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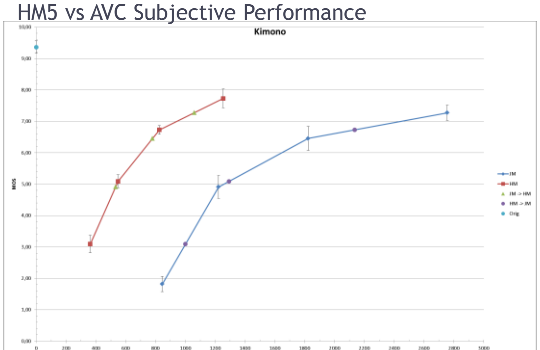
HM5 vs AVC Subjective Performance



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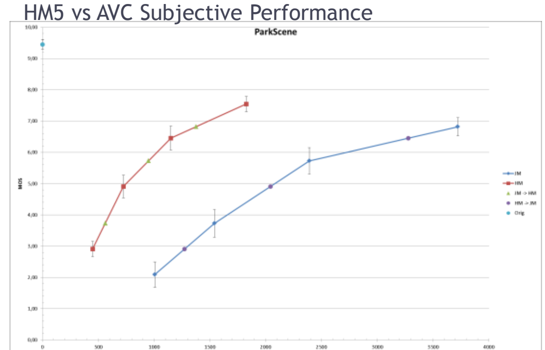
HM5 vs AVC Subjective Performance



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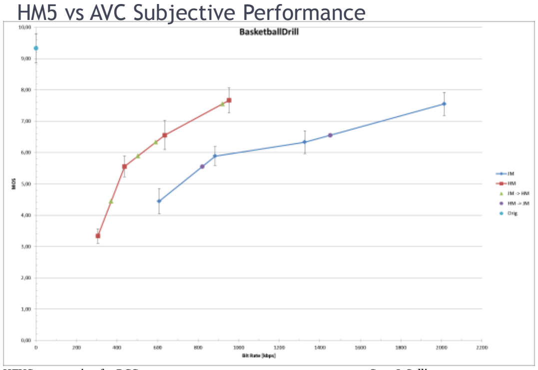
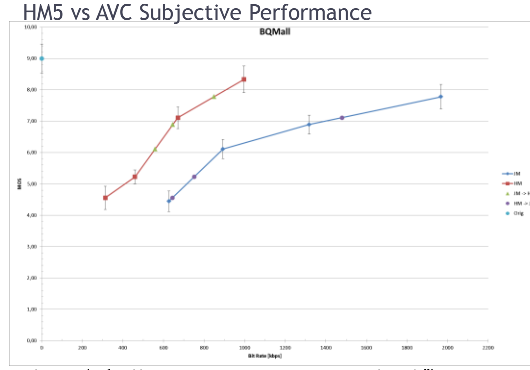
HM5 vs AVC Subjective Performance



HM5 vs AVC Subjective Performance



HM5 vs AVC **Subjective** Performance

- Average bit rate savings computed from interpolated "MOS over rate" graphs (from an separate test, **JCTVC-H0116**, Tan et al.)

Sequences	Bit rate Savings relative to H.264/MPEG4 AVC HP	
	HEVC MP	HEVC all tools
BQTerrace	63.1%	68.7%
BasketballDrive	66.6%	69.6%
Kimono1	55.2%	52.5%
ParkScene	49.7%	53.0%
Cactus	50.2%	52.9%
BQMall	41.6%	46.1%
BasketballDrill	44.9%	44.9%
PartyScene	29.8%	27.9%
RaceHorses	42.7%	48.6%
Average	**49.3%**	**51.6%**

HEVC HM 5 **Subjective** Performance *for Low-Delay Applications*

- Latest **HEVC HM 5.0 High Efficiency** vs. **JM 18.2 AVC High Profile** (ITU-T H.264 | ISO/IEC 14496-10)
- Source: **JCTVC-H0562** by **F. Kossentini, N. Mahdi, H. Guermazi, M. Horowitz, S. Xu, B. Li, G. J. Sullivan, J. Xu** (Jan. '12)
- **Subjective quality** should be measured formally with proper statistical analysis and controlled viewing, but here are some ***informal*** test results
- Same encoding methods as described in **JCTVC-H0360** (similar to prior JCTVC-G399)
- Five video test sequences (**three Class E 720p, two Class B 1080p**)
- Encodings and bit rates selected to represent ***low-delay applications***
- Compared AVC encodings with HEVC encodings at ***half the bit rate***
- In **75%** of test cases, viewers either had no preference or preferred HEVC
- For **4 of 5** video clips, most viewers had no preference or preferred HEVC
- For **3 of 5** video clips, the vast majority who had a preference preferred HEVC (and for one other clip, the preferences rate was nearly equal)
- These test results are *not* officially endorsed by JCT-VC or others

Low-Delay Subjective Assessment Results: SPIE 8499-31 (Horowitz et al)

- Reference encoders: HM 7.1 vs. JM 18.3

Subjective viewing for HM vs. JM									
Sequence	**HM bit rate (kbps)**	**HM QP**	**JM bit rate (kbps)**	**JM QP**	**HM : JM bit rate**	**Votes favoring HM**	**Votes favoring JM**	**% favoring HEVC**	**Total number of votes**
KristenAndSara	149	38	302	37	49%	10	15	40%	25
Vidyo1	190	37	367	36	52%	14	11	56%	25
OldTownCross	408	37	879	37	46%	22	3	88%	25
Kimono1	682	36	1404	35	49%	21	4	84%	25
toys_and_calendar	347	37	734	38	47%	25	0	100%	25
				Average	**49%**	92	33	**73.6%**	125

Low-Delay Subjective Assessment Results: SPIE 8499-31 (Horowitz et al)

- Production encoders: eBrisk vs. x264

Subjective viewing for eBrisk vs. x264									
Sequence	**eBrisk bit rate (kbps)**	**eBrisk QP**	**x264 bit rate (kbps)**	**x264 QP**	**eBrisk : x264 bit rate**	**Votes favoring eBrisk**	**Votes favoring x264**	**% favoring HEVC**	**Total number of votes**
KristenAndSara	332	36	657	33	51%	12	13	48%	25
Vidyo1	363	36	773	32	47%	10	15	40%	25
OldTownCross	904	35	1716	34	53%	22	3	88%	25
Kimono1	1384	35	2670	32	52%	17	8	68%	25
toys_and_calendar	729	36	1553	33	47%	17	8	68%	25
				Average	**50%**	78	47	**62.4%**	125

Complexity & Deployment

- Overall complexity report SPIE 8499-32 (Ahn, Han, & Sim)
  - Based on reference software analysis
  - 25-50% decoder complexity increase relative to H.264/AVC HP
  - Parallelism additionally improved
- Decoder demos by F. Bossen of NTT Docomo in July & October (JCTVC-J0128 & JVTVC-K0327 & JCTVC-L0098)
  - 4k × 2k at 30 fps on a laptop single-threaded
  - 1920 × 1080p at 25 fps on a smart phone single-threaded
  - 1280 × 720 at 30 fps on ARM Cortex A9 clocked at 1 GHz (iPad)
  - 4k × 2k at 60 fps (up to 100 fps) on a laptop three-threaded
  - 720p up to 300 fps on a laptop three-threaded
- *Trans CSVT* Dec. 2012 (F. Bossen, B. Bross, K. Suehring, D. Flynn)
- Encoding complexity is more of a challenge
  - But feasible (eBrisk, Ericsson, Vanguard, Allegro, Rovi, Ateme, NGCodec, Elemental, etc.)
  - Design structure and principles similar to H.264/AVC
  - Design is flexible for selection of aspects to support
  - Parallelism opportunities built in

HEVC extension developments

- Range extensions (JCTVC-L1005 draft)
  - 4:4:4, 4:2:2
  - Increased bit depths
  - Two core experiments underway (JCTVC-L11121 and JCTVC-L1122)
- Scalability "SHVC" (JCTVC-L1008 draft)
  - Hooks for extensions built into version 1
  - Joint call for proposals in 2012
  - 21 proposals received
  - Spatial & SNR enhancements planned
  - Multi-loop coding structure likely
  - AVC base layer possible
  - Five core experiments underway (JCTVC-L1101 to JCTVC-L1105)
- 3D (New JCT-3V partnership)
  - Frame packing in version 1
  - MPEG call for proposals in 2011
  - Multiview & depth map encoding & combined encoding
  - Extensions to AVC as well as HEVC (first extension finished, more)
  - Third Multiview HEVC draft produced (JCT3V-C1004)
  - Seven core experiments underway (JCT3V-C1101 to JCT3V-C1107)

Summary and outlook

- Very active project (**5500**+ documents, **750**+ people)
- Very diverse company & university participation (~**150** institutions)
- Major technical advance over prior standards
- Computational/implementation complexity is reasonable
- Parallelism is an increased theme
- Three profiles in first version, with two bit rate tiers and 13 levels
- Deliverables:
  - Video coding specification
  - Reference software
  - Conformance testing specification
- Systems support under way for MPEG-2 TS, ISO BMFF, DASH, etc.
- Patent pool formation begun in MPEG-LA
- Multiple versions and extensions planned (Rext, 3D/MVC, SVC)
- Contact: JVT, JCT-VC, JCT-3V, VCEG, MPEG video chairs:
  - Gary J. Sullivan (garysull@microsoft.com)
  - Jens-Rainer Ohm (ohm@ient.rwth-aachen.de)

For further information

- Document archives and software are publicly accessible
  - http://hevc.info (general info site with links & papers, maintained by HHI)
  - http://jct-vc.org (http://www.itu.int/ITU-T/studygroups/com16/jct-vc/index.html)
  - http://jct-3v.org (http://www.itu.int/en/ITU-T/studygroups/com16/video/Pages/jct3v.aspx)
  - http://phenix.it-sudparis.eu/jct
  - http://phenix.it-sudparis.eu/jct3v
  - http://ftp3.itu.ch/av-arch/jctvc-site
  - http://ftp3.itu.ch/av-arch/jct3v-site
- Publications
  - **Special Issue on Emerging Research and Standards in Next Generation Video Coding (HEVC)**, *IEEE T-CSVT*, Dec. 2012 (includes technical overview paper, compression capability analysis paper, complexity analysis paper, &c)
  - Nutshell article in *IEEE Commun. Magazine,* Jan. 2013.
  - **Special Section on the Joint Call for Proposals on High Efficiency Video Coding (HEVC) Standardization**, *IEEE T-CSVT*, Dec. 2010
  - "Recent Developments in standardization of High Efficiency Video Coding (HEVC)", *SPIE Appl. Dig. Image Proc.*, Aug. 2010