High Efficiency Video Coding (HEVC) and its Extensions

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Major Video Coding Standards

- These are the joint work of the same two bodies
  - ISO/IEC Moving Picture Experts Group (MPEG)
  - ITU-T Video Coding Experts Group (VCEG)
  - Most recently working on High Efficiency Video Coding (HEVC) as Joint Collaborative Team on Video Coding (JCT-VC)
- HEVC version 1 was completed in January 2013
  - Standardized by ISO/IEC as ISO/IEC 23008-2 (MPEG-H Part 2)
  - Standardized by ITU-T as H.265

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 **H.264 / MPEG-4 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 the decoder is not so tough (~1.5x)**
  - **And the memory increase is not so much**
  - **And the parallelism opportunities are better (throughout)**

Trends demanding more video compression

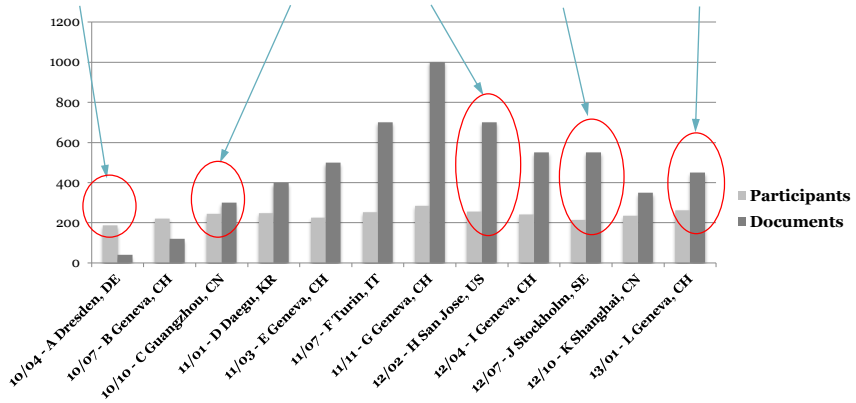
- Video is continually increasing in resolution
  - HD existing, UHD (4Kx2K, 8Kx4K) appearing
  - Mobile services going towards HD
  - stereo, multi-view emerging
- Devices available to record and display ultra-high resolutions
  - Becoming affordable for home and mobile consumers
- Video has multiple dimensions to grow the data rate
  - Frame resolution, Temporal resolution
  - Color gamut, bit depth
  - Multi-view / 3D
  - Visible distortion still an issue with existing networks
- Necessary video data rate grows faster than feasible network transport capacities
  - **Most data traffic is video, with a continually increasing percentage**
  - Better video compression (than MPEG-4 AVC | ITU-T H.264) needed

HEVC and the JCT-VC Partnership

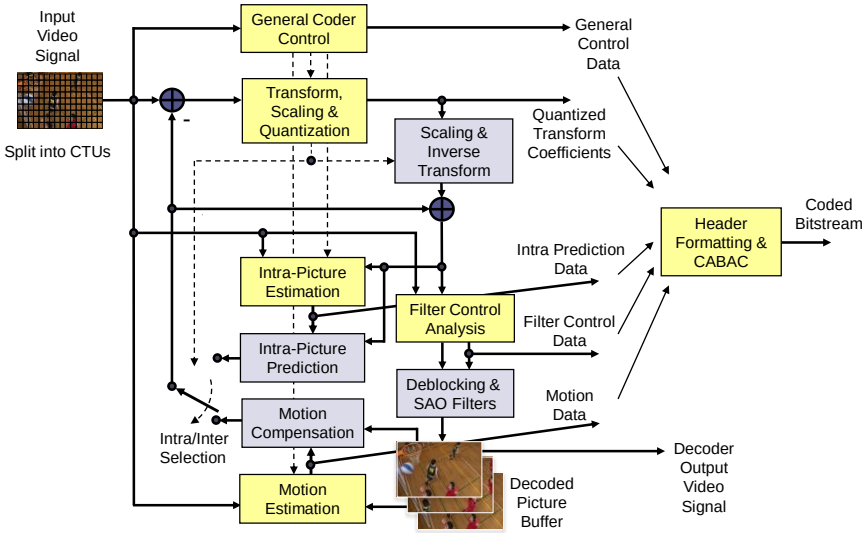
- Initial groundwork in VCEG and MPEG
  - "Key Technical Area" (KTA) study and software in VCEG
  - "Call for Evidence" in MPEG
- Agreement in January 2010 to form new team **VCEG-AM90** / **N11112**
- **Joint Call for Proposals** on Video Coding Technology issued January 2010 **VCEG-AM91** / **WG 11 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
- Document archives and software are publicly accessible
  - http://hevc.info
  - 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

Project Timeline and Milestones

First Test Model under Consideration (TMuC) | First Working Draft and Test Model (Draft 1 / HM1) | ISO/IEC CD (Draft 6 / HM6) | ISO/IEC DIS (Draft 8 / HM8) | ISO/IEC FDIS & ITU-T Consent (Draft 10 / HM10)



HEVC Block Diagram



Comparison of HEVC and AVC

	HEVC	AVC
Coding Tree Unit	64x64, 32x32, 16x16 CTU	16x16 macroblock
Coding Unit	64x64, 32x32, 16x16, 8x8 CU	16x16 macroblock
Prediction Unit	square, symmetric rectangular, asymmetric rectangular PU	square, symmetric rectangular
Transform Unit	32x32, 16x16, 8x8, 4x4 TU	8x8, 4x4 transforms
Intra prediction	33 directional modes, DC, planar	8 directional modes, DC, 16x16-only planar
Motion prediction	multi-candidate MV prediction with spatial & temporal region merging	spatial median or temporal co-located MV prediction
Luma interpolation	¼ pixel 7-tap, ½ pixel 8-tap	½ pixel 6-tap + ¼ pixel bilinear
Chroma interpolation	4-tap	bilinear
Entropy coding	CABAC	CABAC, CAVLC
Loop filtering	deblocking filter, sample adaptive offset (SAO)	deblocking filter
Parallelism	tiles, wavefronts, slices (deblocking filter, SAO, other)	slices

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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 more robust than in AVC

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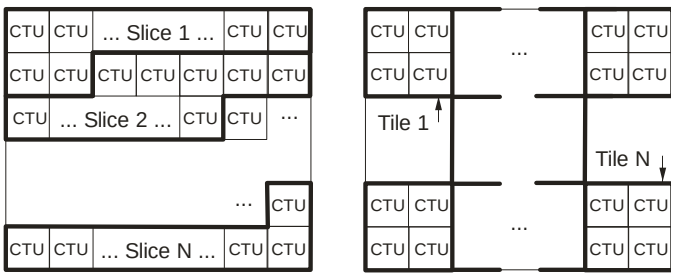
HEVC – Slices, Slice Segments, Tiles, and Wavefronts

- ***Slices*** are independently decodable strings of CTUs of a picture; 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 are rectangular
  - Dividing a picture into regular-sized tiles (fixed number of CTUs), enables efficient parallel processing and provides entry points for local access
  - There can be multiple slices in a tile, or multiple tiles in a slice
- Ordered substreams for ***wavefront parallel processing*** of CTUs that are mutually independent w.r.t. CABAC adaptation

HEVC – Slices and Tiles

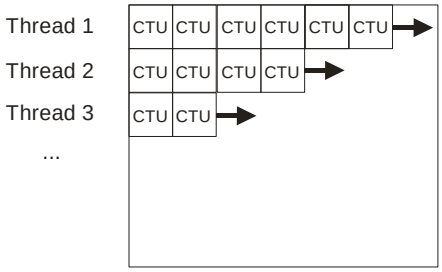
- Typical examples of slice (a) and tile (b) partitioning of a picture



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

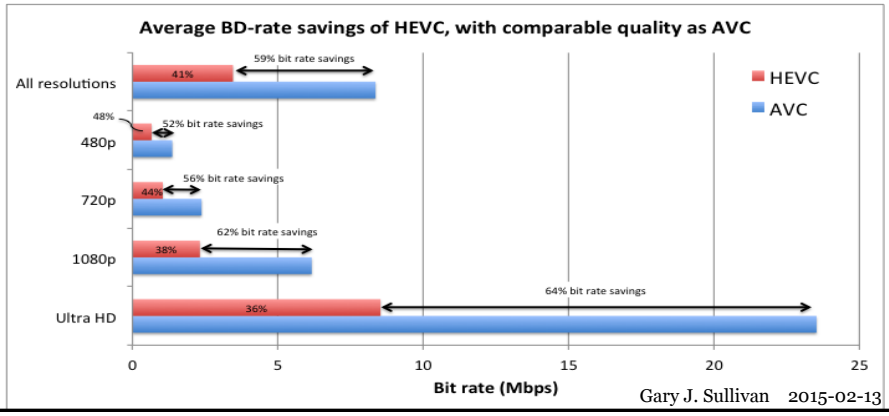
Wavefront Parallel Processing

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



HEVC Version 1 Verification Test

- HEVC version 1 completed January 2013
- Verification test completed April 2014, JCTVC-Q1011
  - Formal subjective test vs. AVC High profile
  - 22 test sequences, various bit rates, 480p to Ultra HD
  - Major gains: UHD (64%), 1080p (62%), 720p (56%) and 480p (52%)



HEVC version 2 extensions (2014)

- Format range extensions “RExt” (~20 profiles!)
  - 4:4:4, 4:2:2, monochrome, all-intra
  - Increased bit depths
  - More color-related metadata (SMPTE 428, 2084, 2086, knee, mapping)
  - Completion April 2014 (a few aspects one meeting later)
- Scalability "SHVC" (~3 profiles)
  - Hooks for extensions built into version 1
  - Spatial, SNR, color gamut, bit depth enhancements
  - Architecturally simple multi-loop “reference index” design
  - Alpha channel, overlays, other metadata
  - AVC base layer possible
  - Completion July 2014
- MV-HEVC for 3D video (~2 profiles)
  - (Frame packing was in version 1)
  - Extensions to AVC as well as HEVC
  - Completion July 2014 for multiview & depth map encoding
  - Combined 3D encoding designed (but to be in next version)

HEVC Screen Content Coding Extensions (2016)

- CfP issued January 2014
- 7 responses evaluated (JCTVC-Q0031 – JCTVC-Q0037)
  - Qualcomm, ITRI, MediaTek, Huawei, Microsoft, Mitsubishi Electric, Interdigital
- Very substantial gain shown
- Included new capabilities (more possible)
  - Intra block copy
  - Adaptive color transform
  - Palette mode
  - Adaptive MV resolution
- Schedule:
  - First Test Model April 2014
  - Working draft 1 July 2014
  - Working draft 2 Oct 2014
  - PDAM Feb 2015
  - DAM June 2015
  - FDAM & Consent Feb 2016

Summary and outlook for HEVC

- Very active work (many documents & people per meeting)
- Very diverse company & university participation
- 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 developed for MPEG-2 TS, ISO BMFF, DASH, etc.
- Multiple versions and extensions (RExt, 3D/MVC, SHVC, SCC)
- 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 info - links

- Document archives and software are publicly accessible
  - http://hevc.info
  - 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

For further info - publications

- Publications
  - HEVC books by Wien and by Sze, Budagavi & Sullivan
  - "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, and others)
  - Nutshell article in *IEEE Commun. Magazine,* Jan. 2013.
  - "Standardized Extensions of High Efficiency Video Coding", *IEEE Journal on Selected Topics in Signal Processing*, Vol. 7, no. 6, pp. 1001–1016, Dec. 2013
  - Upcoming special issue of *IEEE T-CSVT*