Versatile Video Coding (VVC) Delivers: Coding Efficiency and Beyond

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based primarily on slides prepared by

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Versatile Video Coding (VVC)

Joint ITU-T (VCEG) and ISO/IEC (MPEG) project, completed July 2020

Rec. **ITU-T H.266** & **ISO/IEC 23090-3**

Coding Efficiency

~50% saving over H.265/HEVC

emph. HD / UHD / 8K resolutions
emph. HDR / WCG
emph. 10 bit

Versatility

Rendered "screen" content coding
Adaptive resolution changes
Independent sub-pictures
Tiles, slices and wavefronts
Layered multistream & scalability
Bitstream extraction and merging
360° video projection handling
Random access & splicing features
Gradual decoder refresh

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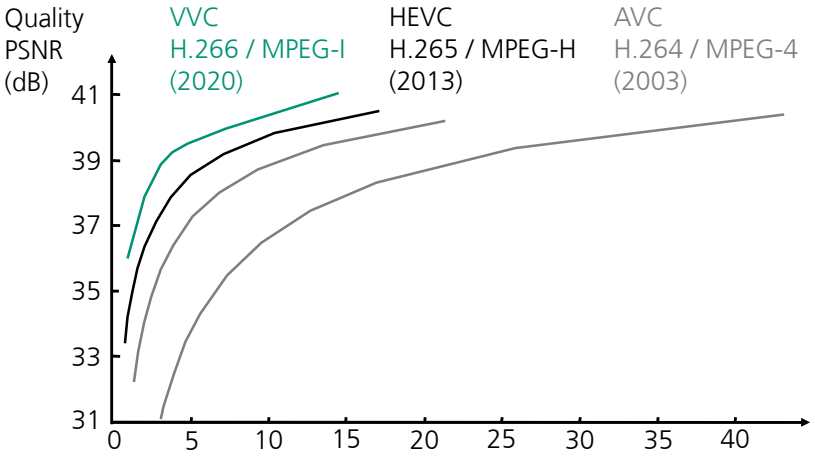
History of Video Coding Standards



BasketballDrive (1920 x 1080, 50Hz)

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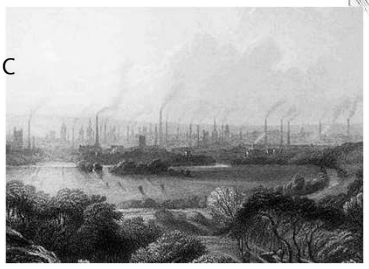
VVC – Coding Efficiency

Jevons Paradox

"The efficiency with which a resource is used tends to increase (rather than decrease) the rate of consumption of that resource."

Video is 80% of internet traffic (and rising)



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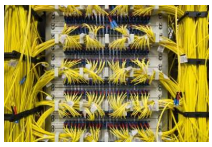
Video Coding Consumption 2018–2020

80%

of all Internet

traffic is now video



12X

increase in AR/VR

traffic

7X

increase in video

monitoring traffic

* Cisco Visual Networking Index: Forecast and Trends, 2017–2022 (2018)

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VVC – Timeline

2015 Oct. – Exploration Phase

- Joint Video Exploration Team (JVET) of ITU-T VCEG and ISO/IEC MPEG established October '15 in Geneva
- Joint Video Exploration Model (JEM) as software playground to explore new coding tools
- 34% bitrate savings for JEM relative to HEVC provided evidence to start a new joint standardization activity with a…

2017 Oct. – Joint Call for Proposals (CfP)

- Submit bitstreams and decoded video for proposed video coding technology
- Compare submission with HEVC anchor for given sequences, bit rates and coding conditions

2018 Apr. – Development Phase

- Subjective evaluation results of submitted CfP responses and HEVC anchor
- Initial starting point of standard development

2020 Jul. – Final Standard (VVC, also *Versatile Supplemental Enhancement Information – VSEI*)

VVC – Call for Proposals

Results

- JVET received submissions from 32 organizations.
- 40% or more bit rate savings in terms of PSNR over HEVC were shown.
- All submissions were superior in terms of subjective quality than…
  - HEVC (in most test cases)
  - JEM (in a relevant number of test cases)

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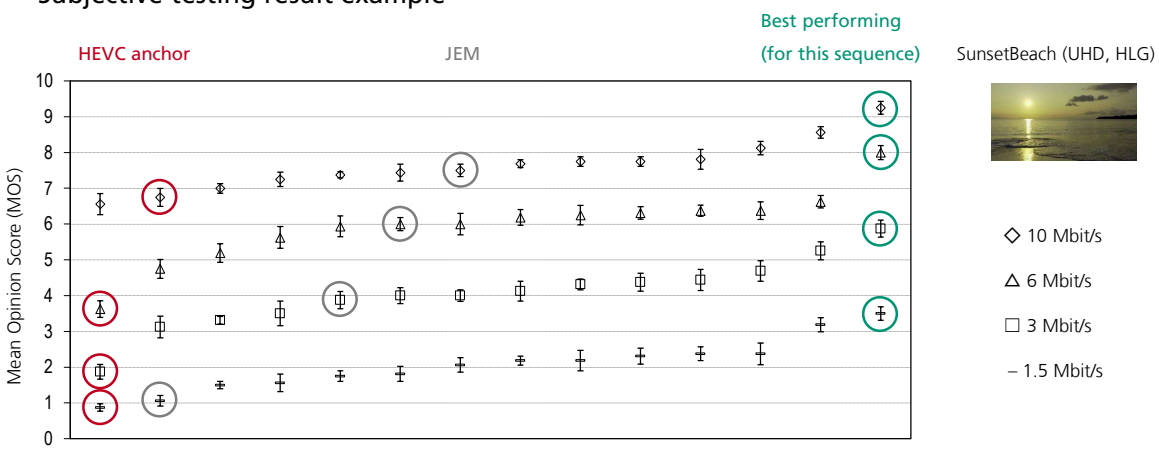
VVC – Call for Proposals

Subjective testing result example



JVET-J0080: "Results of Subjective Testing of Responses to the Joint CfP on Video Compression Technology with Capability beyond HEVC", 10th JVET Meeting, San Diego, April 2018

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VVC – Development

Draft 1 and First Test Model (VTM-1.0)

- Started off with a clean slate
- Based on quadtree plus multi-type tree block partitioning (QT+MTT)
  - Fundamental impact on all coding tools to be added
  - Most common partitioning scheme among all CfP submissions
- VVC Test Model (VTM) as reference implementation
- Test promising coding tools from CfP on that lean basis (efficiency / complexity aspects)
- Agree on adding tested coding tools until sufficient bitrate reduction is achieved

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VVC – New Coding Tools (beyond HEVC v1)

Block Segmentation

- Quadtree with Multi-Type Tree
- Larger max CU size
- Sub-Picture Segmentation
- Chroma Separate Tree
- Local Dual Tree
- Virtual Pipeline Data Units

Intra Prediction

- 93 prediction angles! (65 for each block size)
- 4-tap interpolation filters
- Position-Dependent Prediction Combination
- Multiple Reference Lines
- Matrix-based Intra Pred.
- Cross-Component Linear Model
- Intra Sub-Partitions

MV Pred & Deltas

- History-based MVP
- Pair-wise Average MVP Candidate
- Subblock-Based Temporal MVP
- Adaptive MV Resolution
- Merge with MVD
- Symmetric MVD

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VVC – New Coding Tools (beyond HEVC v1)

Inter Prediction

- Geometric Partition Mode
- Reference Picture Resampling
- Bipred with CU Weights
- Combined Intra/Inter Pred
- Decoder MV Refinement
- Affine Motion
- Prediction Refinement with Optical Flow
- Bi-Directional Optical Flow

Transforms & Quant

- Larger & Non-square Transforms
- Multiple Transform Selection
- Low-Frequency Non-Separable Transform
- Sub-Block Transform
- Dependent Quantization
- Joint Coding of Chroma Residuals
- Local Chroma QP Offset

Entropy Coding

- Multi-Hypothesis Probability Estimation
- Additional Coefficient Group Sizes
- Single Reverse Diagonal Scan Order
- Improved Probability Model Selection for Absolute Levels

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VVC – New Coding Tools (beyond HEVC v1)

In-Loop Filtering

- Luma Mapping with Chroma Scaling
- Deblocking Boundary Handling Modifications
- Deblocking Long Filter
- Deblocking Strong Chroma Filter
- Luma-Adaptive Deblocking
- Adaptive Loop Filter
- Cross-Component ALF

Screen Content Tools

- Block-Level DPCM
- Transform-Skip Residual Coding
- Intra Block Copy
- Palette Mode
- Adaptive Color Transform

360° Coding Tools

- MV Wrap-Around
- Virtual Boundaries

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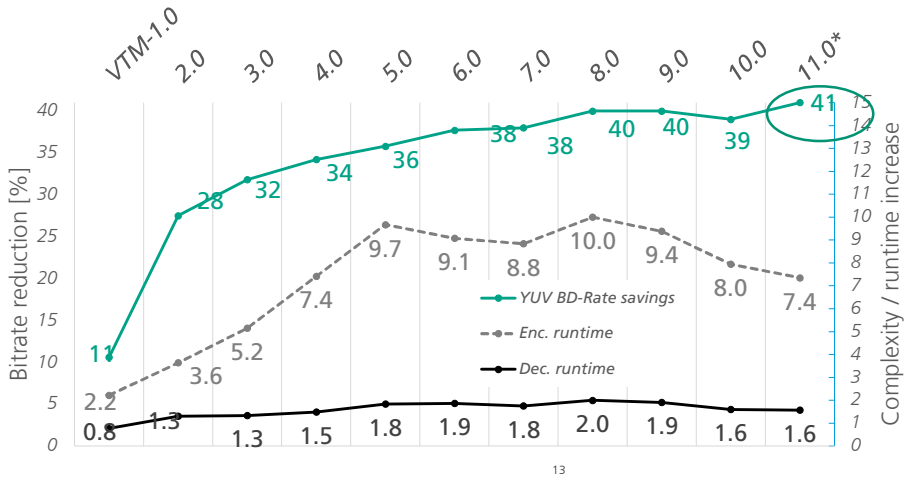
VVC – Coding Efficiency

VVC reference software (VTM) vs. HEVC reference software (HM)



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Even higher than HEVC vs. AVC

Subjective gains seem a bit higher

* Additional gain in VTM-11 is due to GOP config. GOP32 is not supported in HEVC when operating at high resolution. MCTF is used in both configs for VTM 11 comparison.

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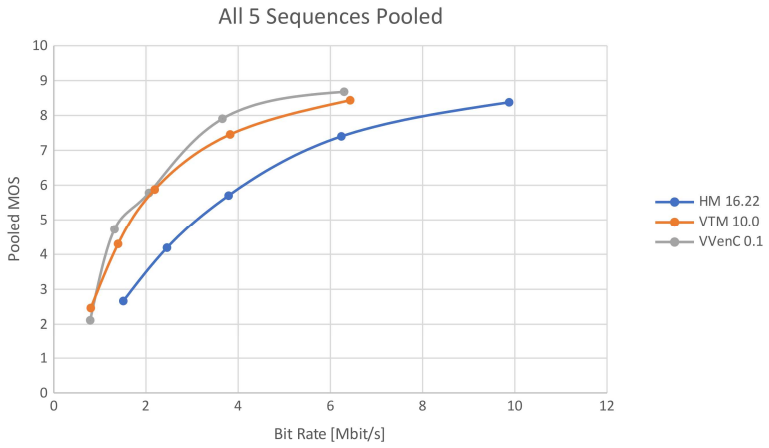
VVC – Coding Efficiency

VVC reference software (VTM) vs. HEVC reference software (HM)



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UHD SDR subjective verification testing Oct 2020

Subjective gain

- ~43 % for VTM enc reference software
- ~49 % for VVenC (>100x faster, subjective opt.)

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VVC – Versatility

Screen content coding (SCC)

Application

Gaming, screen sharing / remote desktop,…

Arena of Valor (1080p60)

Problem

- Video codecs typically optimized for natural video (different signal characteristic)
- Reduces coding efficiency for screen content

Solution

- Special screen content coding tools
- HEVC v4 SCC extensions -> not in main profile!
- VVC supports SCC already in v1 Main profile

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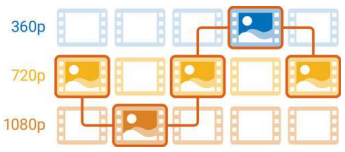
VVC – Versatility

Adaptive resolution change

Application

Adaptive streaming with resolution switching



Problem

- Different resolution reference pictures cannot be used in inter-picture prediction
- Reduces coding efficiency at switching points

Solution

- Resample different resolution reference picture
- VVC supports reference picture resampling (RPR)
- RPR as enabler for spatial scalability in VVC v1

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VVC – Versatility

Tile-based streaming

Application	Problem	Solution
Tiled streaming of 360-degree videos	▶ Managing a decoder sample budget dynamically post-encoding ▶ Throwing 24K video (tiles) at a 4K decoder	▶ More efficient coding of independent sub-pictures (in-picture padding) ▶ Flexible block addressing for easier extraction and merging of sub-pictures

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VVC – Profiles

(Six, logically related)

1) Main 10 profile: monochrome and 4:2:0, 8 to 10 bits, 1 layer
2) Main 10 Still Picture profile: based on the Main 10 profile, 1 picture only
3) Main 10 4:4:4 profile: based on Main 10 profile, also supports 4:2:2 and 4:4:4
4) Main 10 4:4:4 Still Picture profile: based on the Main 10 4:4:4 profile, 1 picture only
5) Multilayer Main 10 profile, based on the Main 10 profile, >= 1 layer
6) Multilayer Main 10 4:4:4 profile, based on the Main 10 4:4:4 profile, >= 1 layer

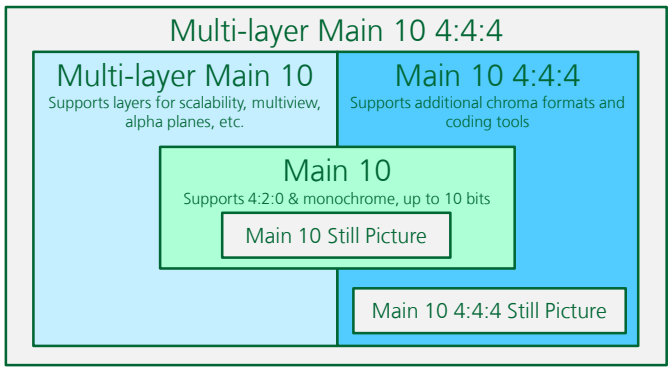

Figure originally by Virginie Drugeon of Panasonic

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Early Deployments (cf. JVET-V0021)

Public Source Code

- JVET VTM reference software
- InterDigital JVET-T0061 multithreaded decoder
- Fraunhofer HHI VVenC encoder
- Fraunhofer HHI VVdeC decoder
- FAU bitstream analyser

Software Decoders

- Sharp JVET-S0224 (4K decode more than 60 fps)
- Tencent O266dec (with mobile platform support)
- Alibaba Ali266 (for mobile platforms)
- VTM, Interdigital, and Fraunhofer HHI (prev. column)

Encoder Prod & Svcs

- KDDI Research (4K@60 fps)
- Ateme Titan (with initial OTT channel Nov 2020)
- Fraunhofer HHI VVenC (prev. column)
- Bitmovin, based on VVenC

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Technical Support (cf. JVET-V0021)

Bitstream Analysers

- Elecard (April 2020)
- ViCueSoft (late 2020)
- FAU software (prev. slide)

Conformance Testing

- JVET Conformance Testing standard
- AllegroDVT (Jan 2020)

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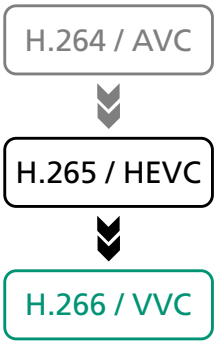
Versatile Video Coding (VVC)

Summary

- Coding Efficiency – VVC Test Model 11 over HEVC (HM)
  - ~41% PSNR-based bit rate reduction for HD and UHD
  - ~7.4x encoder and 1.6x decoder runtime
- Versatility – enabled by:
  - Screen content coding tools (gaming, screen sharing,…)
  - Reference picture resampling (adaptive streaming)
  - Spatial scalability using RPR filters, also temporal, view, quality scalability
  - Independent sub-pictures (360 video, ROI)
  - Boundary handling for 360° video & gradual decoder refresh
  - Bitstream extraction & merging
  - Random access & splicing features
- Final Standard established July 2020 (published by ITU on 10 Nov., ISO in Feb.)
- Deployment & technology support begun [21]



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Future Work Under Consideration

- High bit rate / high bit depth extension
  - Transform precision
  - Entropy coding
  - Possible coding tool reductions
- Additional supplemental information (VSEI standard)
  - Scalability dimension information
  - Extended dependent random access point
  - SEI previously developed in the HEVC or AVC context
  - More under study
- Neural Network Based Technology
  - As individual tools (e.g., prediction mode, in-loop filter, or resolution enhancer)
  - As an end-to-end approach
- Other Technology (JVET-U0048/JVET-U0100: ~12% so far, 2.4x encode, 4x decode)

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Thank you very much!

See also the ICME tutorial:

Versatile Video Coding: Algorithms and Specification
by Mathias Wien and Benjamin Bross

https://signalprocessingsociety.org/community-involvement/multimedia-signal-processing

https://www.youtube.com/watch?v=j045KuFU2QM

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