Transforming **Video Delivery**

Next-Generation Video Compression: VVC and a couple others

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From HEVC to VVC

- About ATEME
- Codecs history
- VVC standardisation
- VVC contenders
- The future of codecs

About ATEME

Contributing to VVC development

Standardization

MPEG

ITU

SMPTE

DVB Digital Video Broadcasting

ATSC

3GPP A GLOBAL INITIATIVE

Forum

Alliance for Open Media

MC-IF.org

Ultra HD FORUM

VR INDUSTRY FORUM

Collaborative projects

EFIGI Efficient Future & nEw Generation vIdeo coding

bpifrance · îledeFrance

CONVERGENCE TV

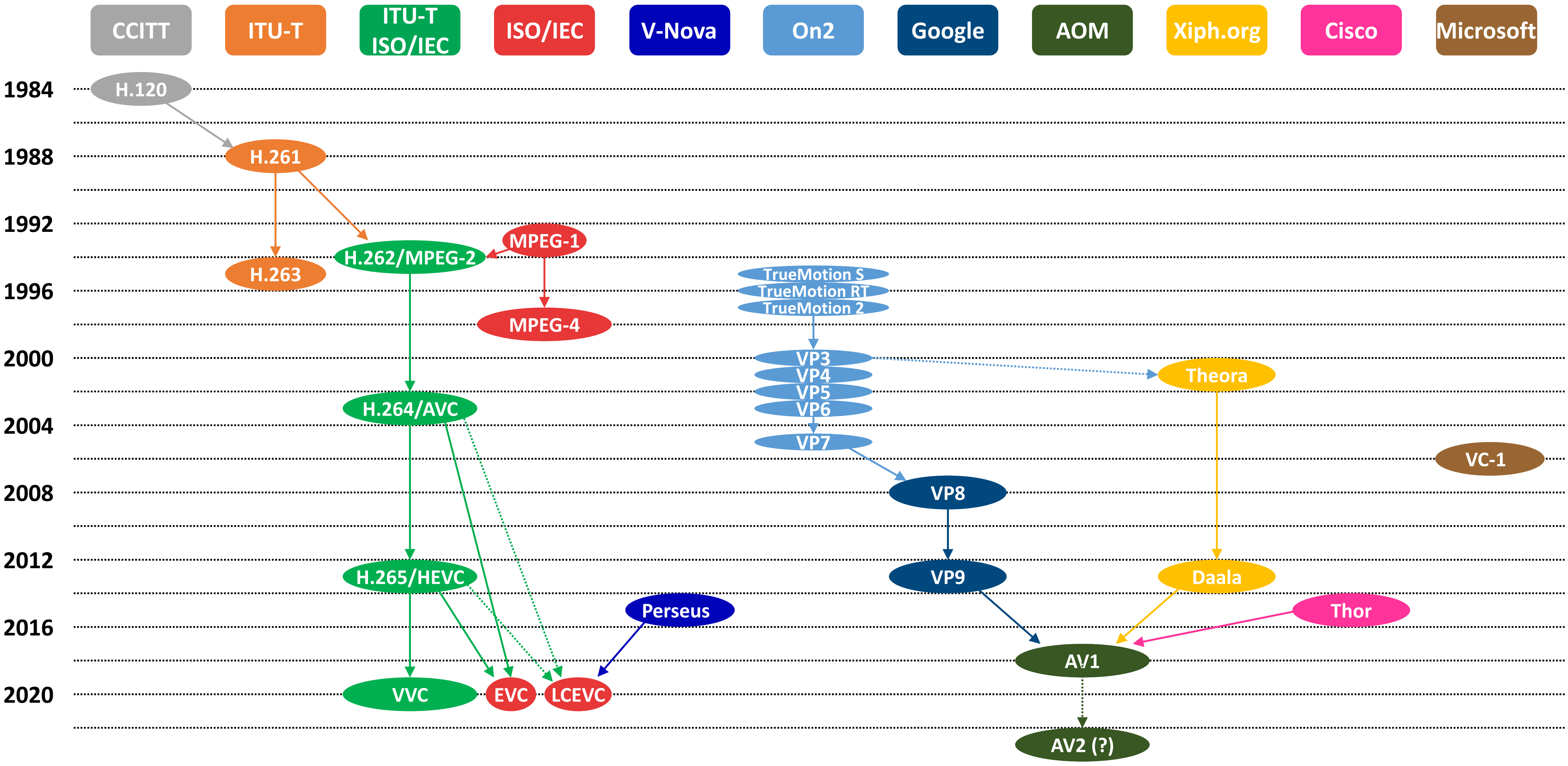
bpifrance · îledeFrance · Région Bretagne

EPFL École Polytechnique Fédérale de Lausanne · Union Européenne · NovelSat Making Space in Space

îledeFrance · Union Européenne

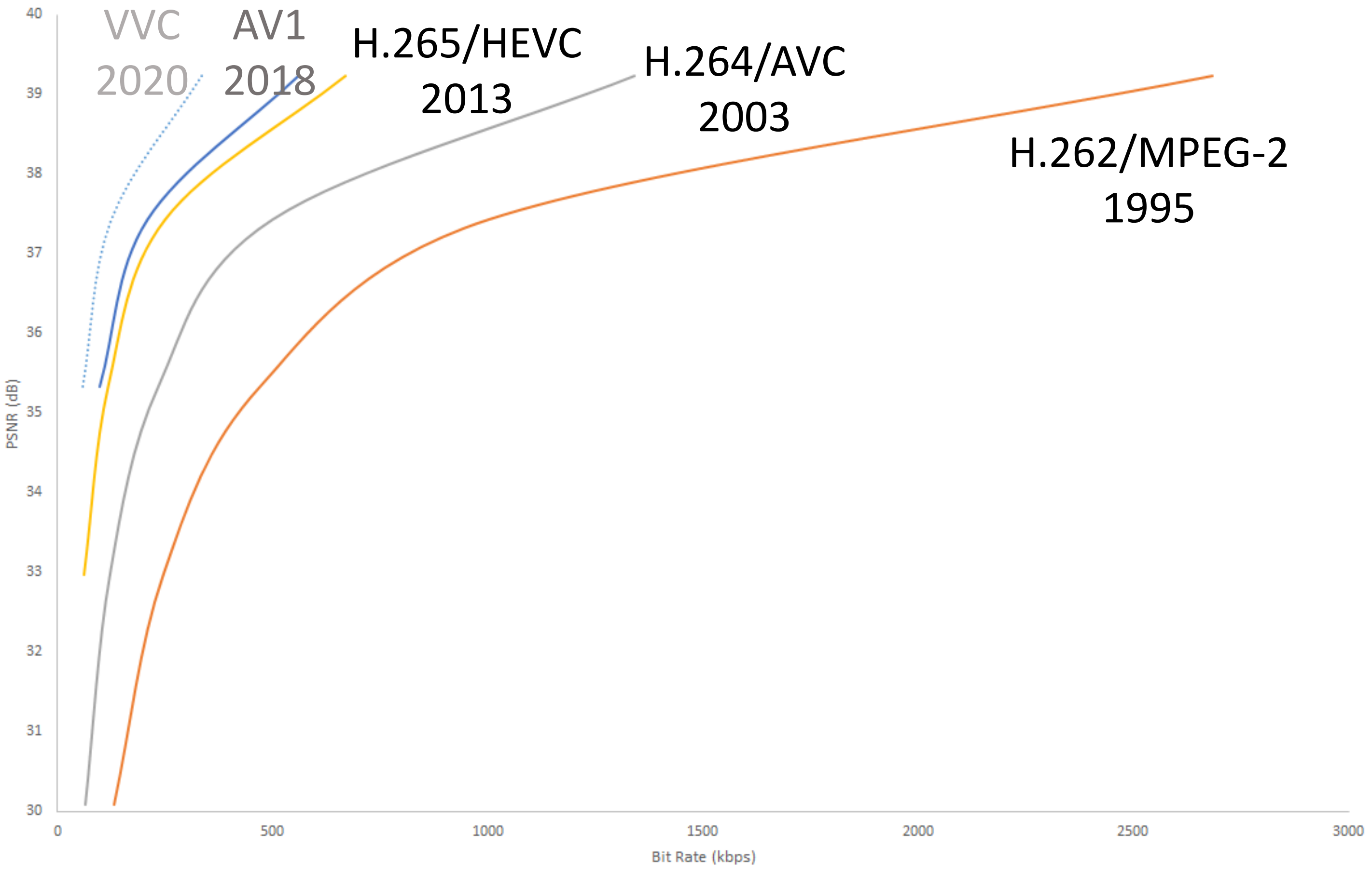
Codecs history

Short Codecs History



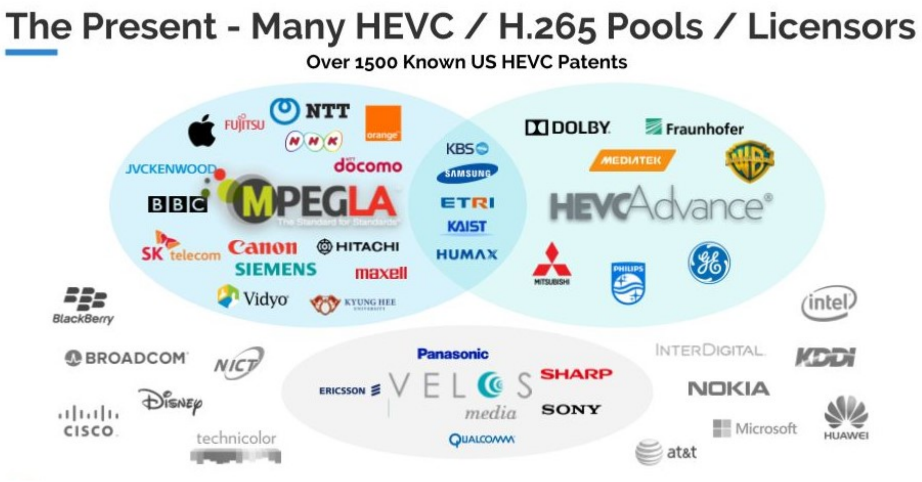
Performance evolution

- About 50% coding performance gain between each major generation
  - Lastly:
    - 35% objective
    - 50% subjective
- VVC on the way
  - 37% objective gain
- Complexity increasing accordingly
  - **Order of 6-10x at each generation**



Codecs licensing bright and dark sides

- Modern codecs are a collection of technologies owned by many parties
- In the 1990s, MPEG-2 adoption was challenged by the access to essential patents
- **MPEG LA** (Licensing Administrator) as « the first modern-day patent pool »
  - Enforcing licenses agreements
  - Collecting and distributing royalties
- 2003, H.264 AVC licensing granted to MPEG LA
  - + many companies managing patents individually
- 2013, H.265/HEVC goes to MPEG LA again, **but:**
  - **New patent pools emerged**
  - Number of contributors multiplied
  - Not all IP owners conformed
  - Licensing and cost of HEVC got confusing
  - HEVC adoption was delayed



Source: Unified Patents –January 9, 2019.

Codec licensing: reacting to the HEVC situation

Leonardo Chiariglione: “MPEG has been developing standards having the best performance as a goal, irrespective of the IPR involved. […], but the patent pool creation mechanism seems no longer able to deliver results.”

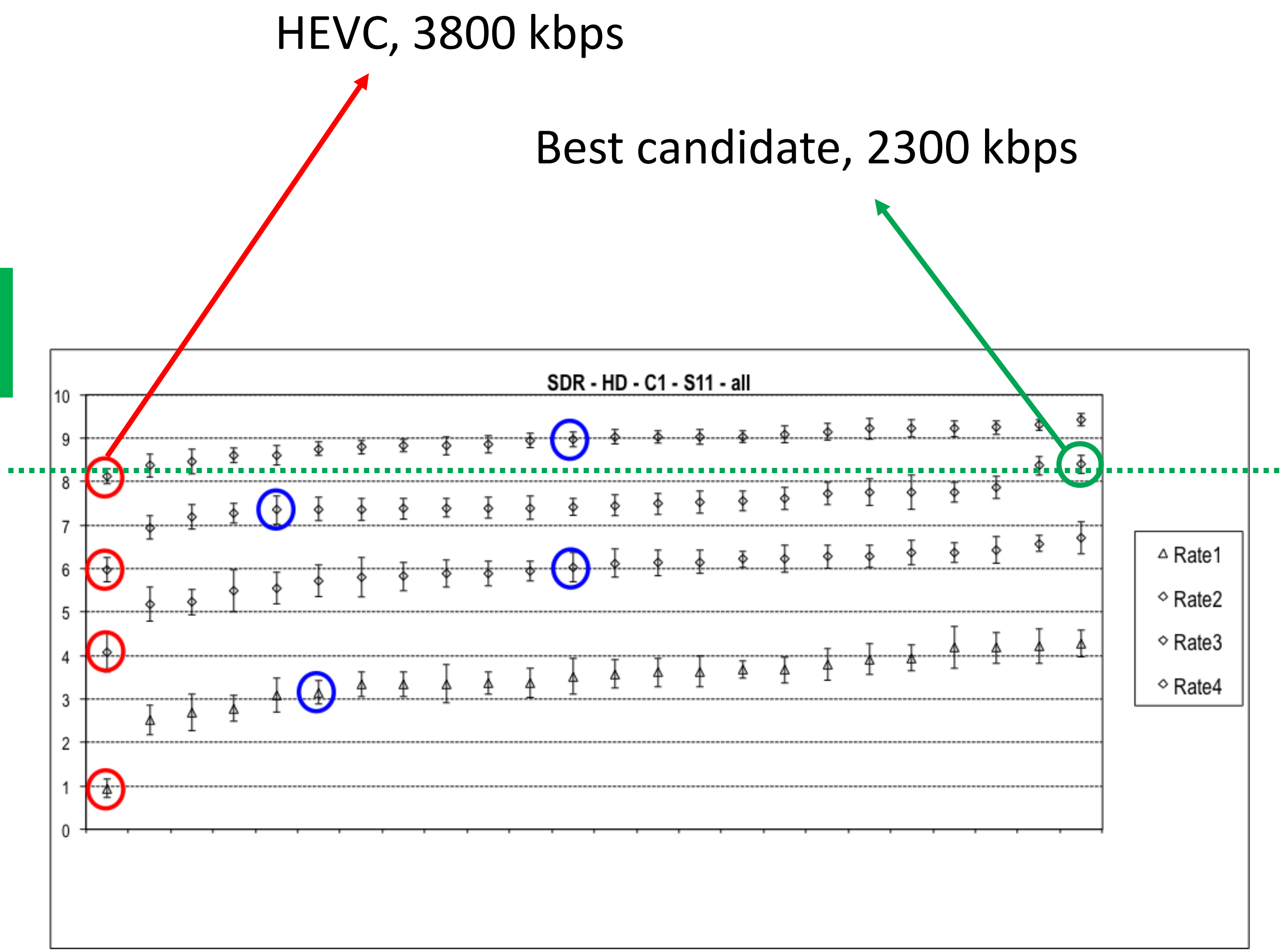
- Royalty free **AV1** developed by the Alliance for Open Media (AOM), led by Google (oct 2018)
- MPEG-5 part 1, Essential Video Coding (**EVC**), a royalty-free / royalty-friendly effort from MPEG
- **Creation of the open industry Media Coding Industry Forum (MC-IF)**
  - Establishing MPEG Standards as well-accepted and widely used standards for the benefit of consumers and industry.
  - Initially focusing on VVC
- **VVC switchable tools strategy**

Leonardo Chiariglione: “We could introduce fractional options in the sense that proposers could indicate that their technologies be assigned to specifically identified profiles with an 'industry licence’ […].”

VVC Standardization

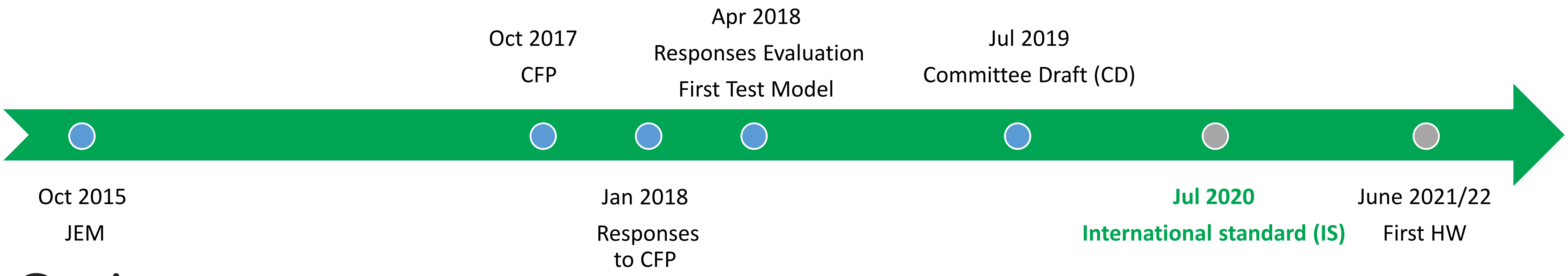
VVC standardisation: do we have better technology?

- **2015, October: exploration phase**
  - Joint Video Exploration Team (JVET) of ITU-T VCEG and ISO/IEC MPEG
  - Joint Video Exploration Model (JEM) software
  - 2 years later, 34% bitrate savings relative to HEVC
- **2017, October: Joint Call for Proposals (CfP)**
  - **Targeting 50% bitrate savings relative to HEVC**
  - **Addressing all kinds of contents**
  - large set of video content defined for evaluation incl. HD, UHD, HDR, and 360
  - 32 submissions
- **2018, April: cfp results**
  - Up to 42% objective bitrate savings (higher than JEM)
  - Subjective tests: for some sequences, more than 50% bitrate savings
- **Say hello to Versatile Video Coding (VVC)**



VVC standardisation: development

- **Draft 1 and First Test Model (VTM-1.0)**
  - HEVC with some coding tools removed
  - Quadtree plus multi-type tree block partitioning (QT+MTT)
    - Most common partitioning
    - Large coding gain (~15%)
- **From this clean basis**
  - Define Common Test Conditions (CTC)
  - Evaluate proposed coding tools (both efficiency and complexity aspects)
  - Agree on tools addition until sufficient performance is reached
- **Incremental process**
  - Draft 7.0 and VTM 7.0 as of January 2020

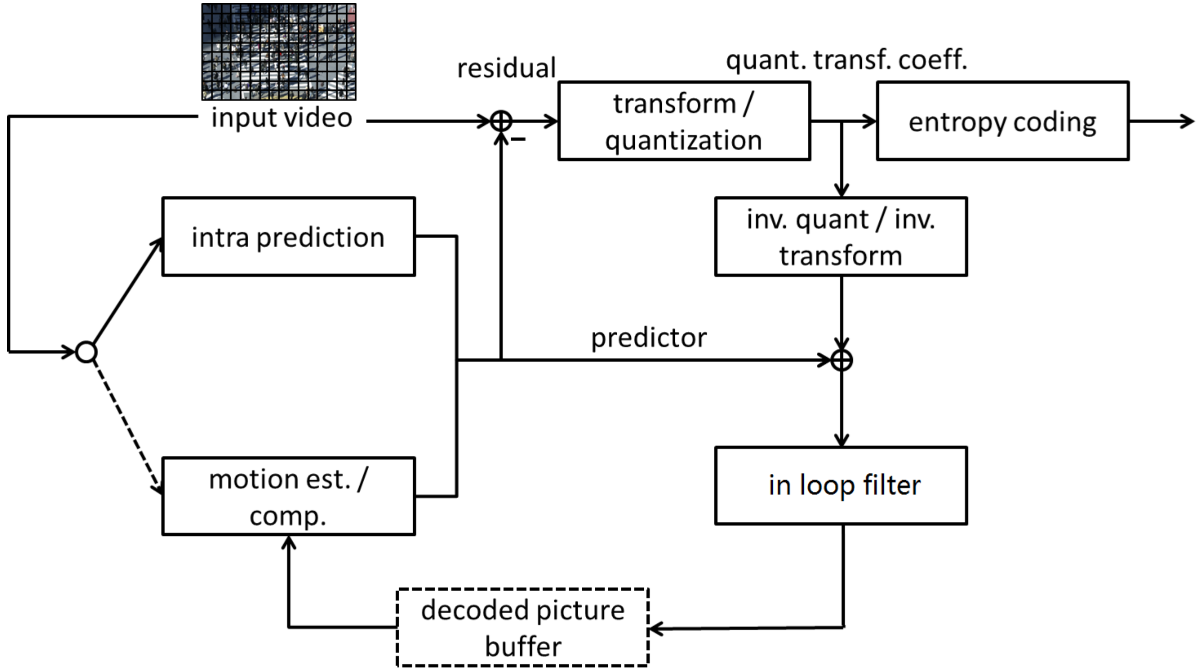


Say hello to Versatile Video Coding (VVC)

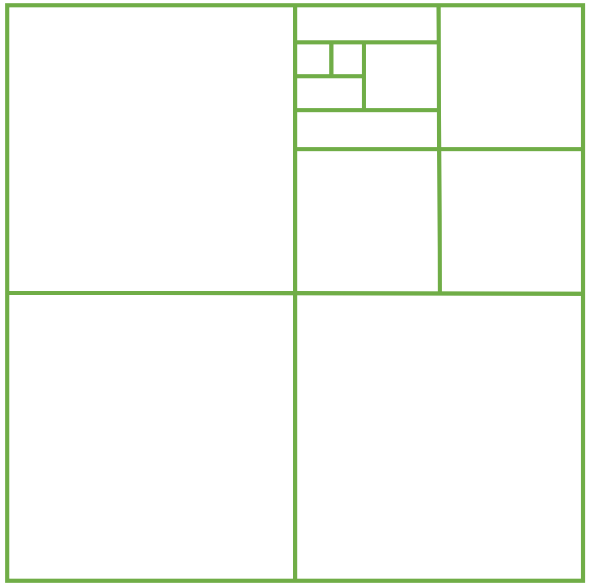
- Classical block-based hybrid coding architecture
  - Intra-frame prediction
  - Inter-frame prediction
  - Residual transformation and quantization
  - Entropy coding

- Each module has been significantly improved since HEVC

- Verification software:
  - VVC Test Model (VTM)
  - Current version: VTM-7

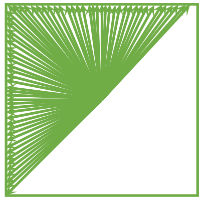


HEVC vs. VVC



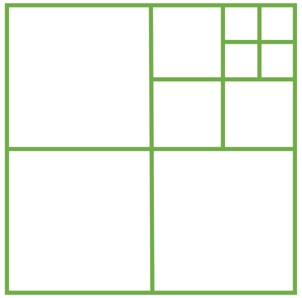
Largest Coding Unit: 128x128
Split patterns:
- Quad
- Ternary
- Binary

Intra:
- 67 modes
- Advanced tools for reference selection, pixel prediction, etc.



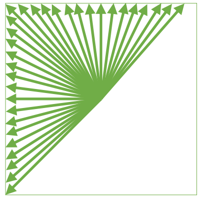
Inter:
- Non-rectangular shapes
- Generalized motion representation

Residual coding:
- Multiple primary transforms e.g. DST-I, DCT-II, DCT-V, etc.
- Non-separable secondary transform
- Dependent quantization



Largest Coding Unit: 64x64
Split patterns:
- Only quad

Intra:
35 modes

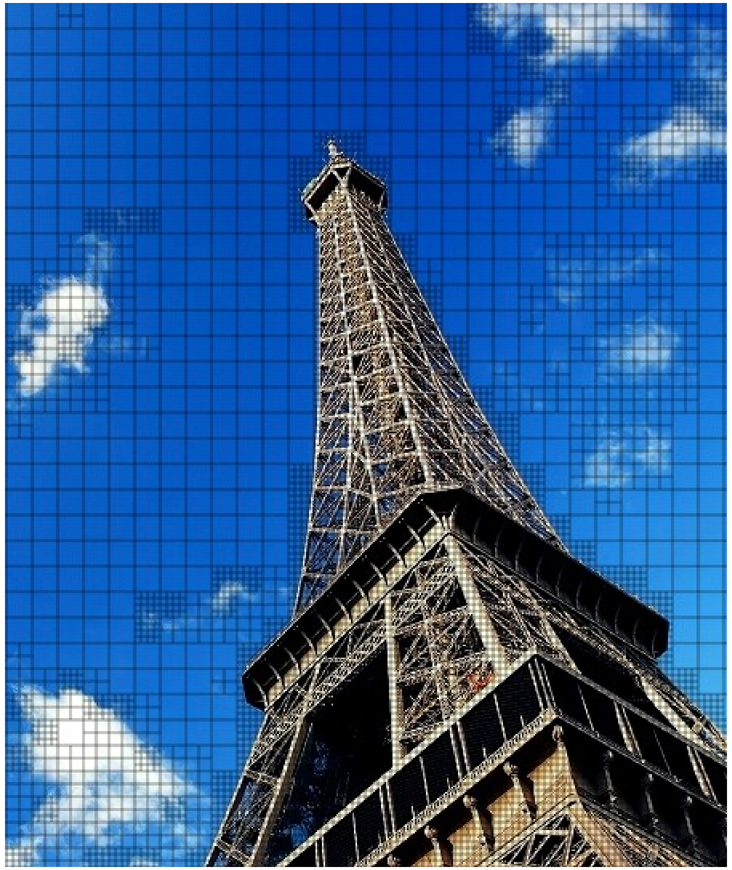


Inter:
- Rectangular shapes
- Linear motion

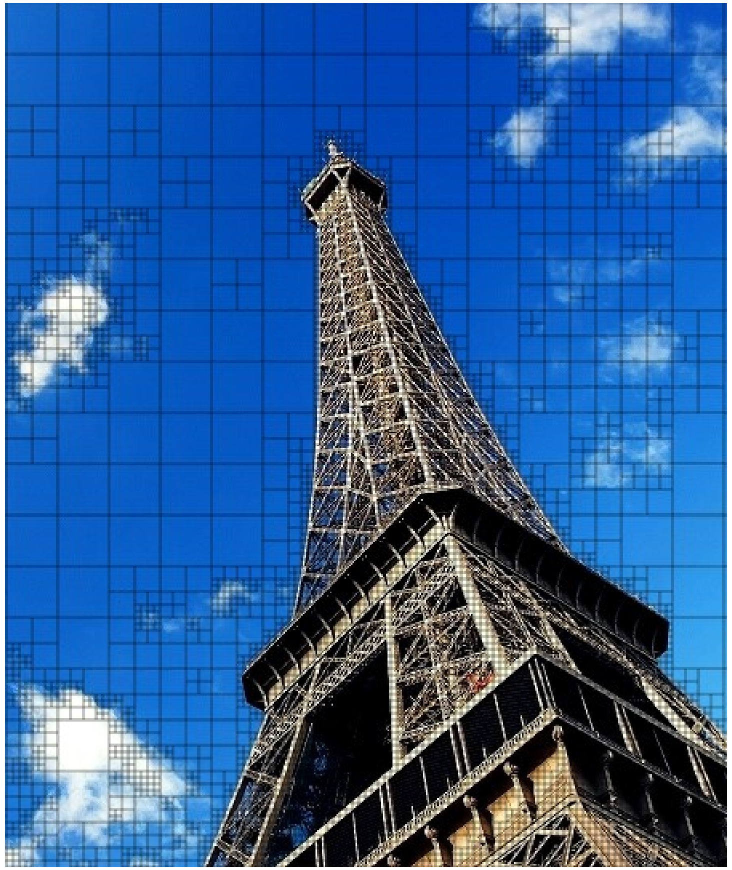
Residual coding:
- Single transform DCT-II or DST-I
- Residual Quad-Tree

Picture partitioning

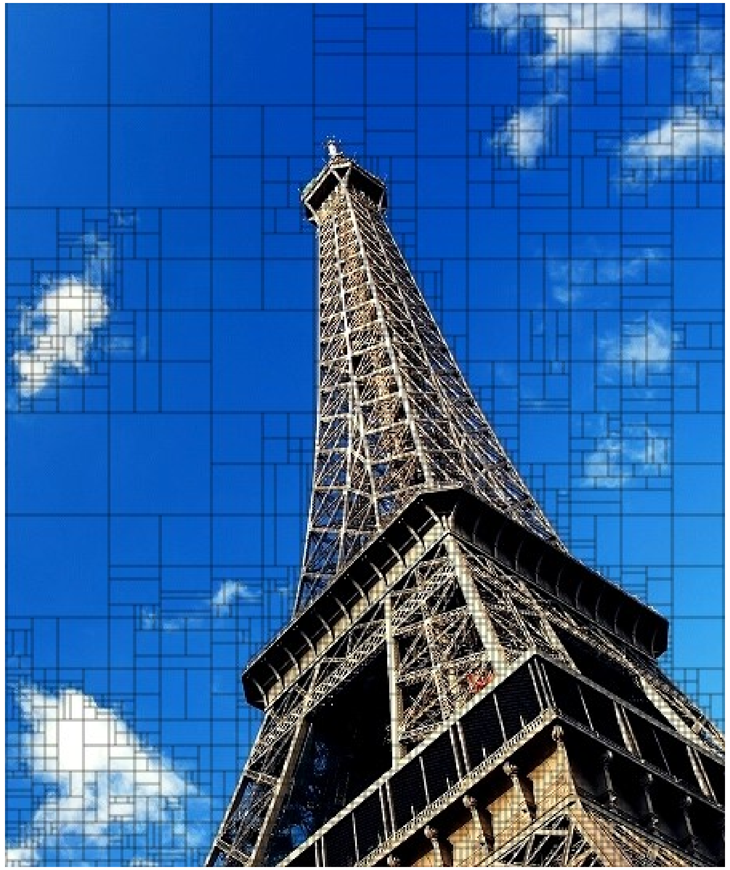
H.264 / AVC



H.265 / HEVC

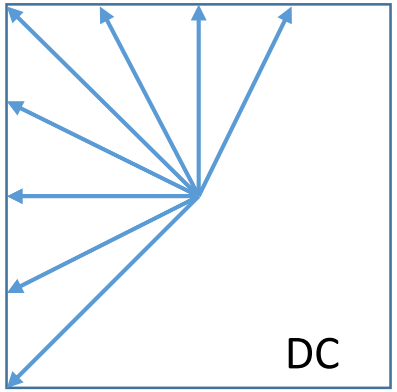


H.266 / VVC

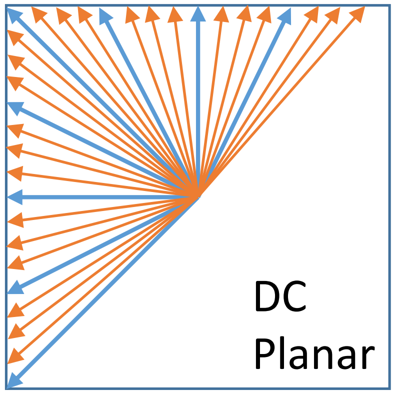


Intra coding: prediction modes

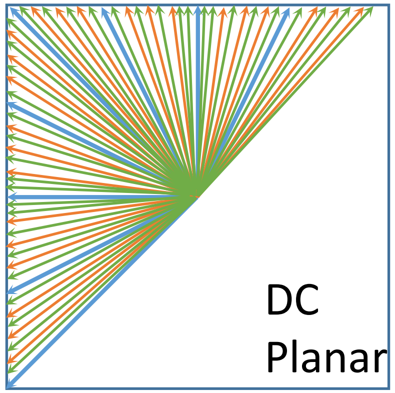
- AVC:
  - 9 modes,
  - Including one DC mode



- HEVC:
  - 35 modes,
  - Including planar and DC

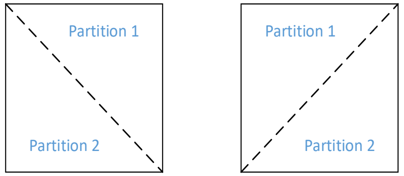


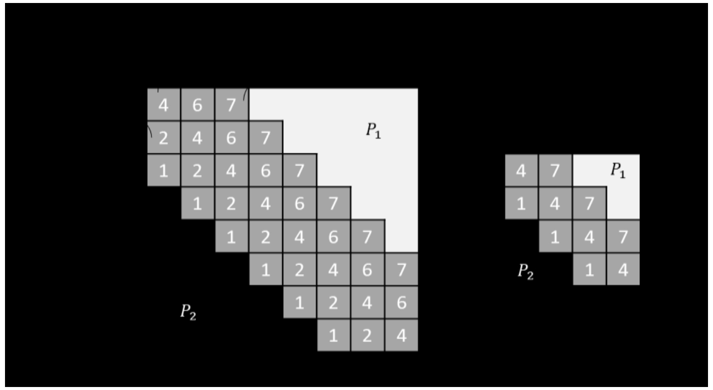
- VVC:
  - 67 modes,
  - Including planar and DC



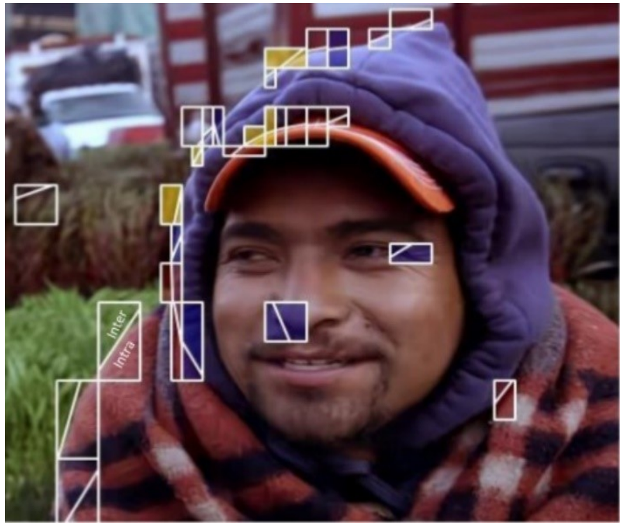
Inter prediction: partitioning

- Triangular partitions
  - Less coding artifacts e.g staircase effect
  - Sharper contours

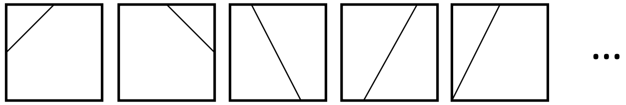




- Combined intra and inter prediction
  - Preserving background details
  - Proper for logo coding

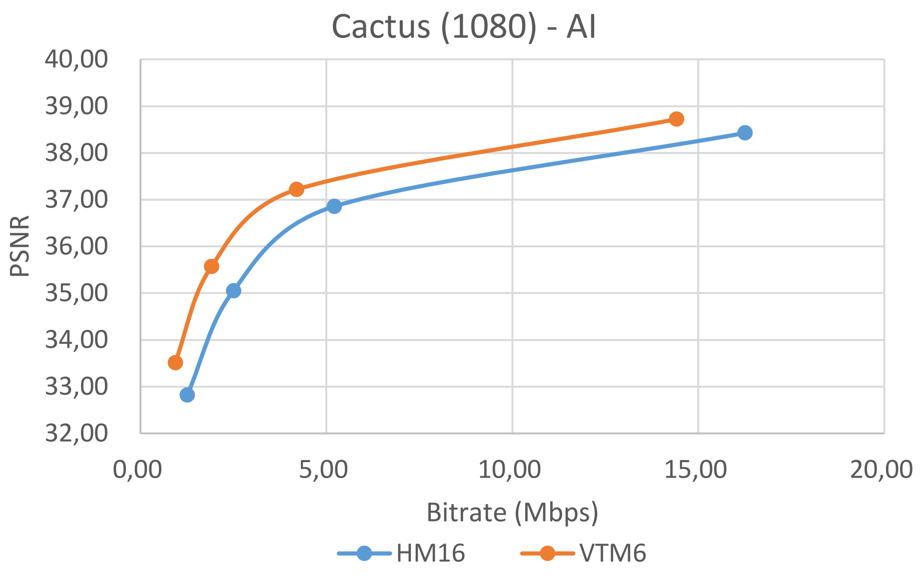


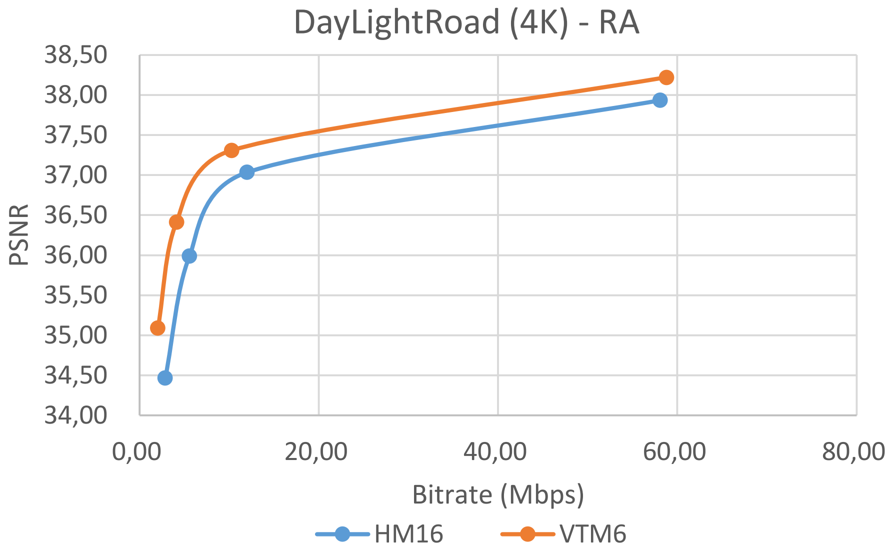
- Geometric (GEO) partitioning
  - Further object-oriented coding shapes



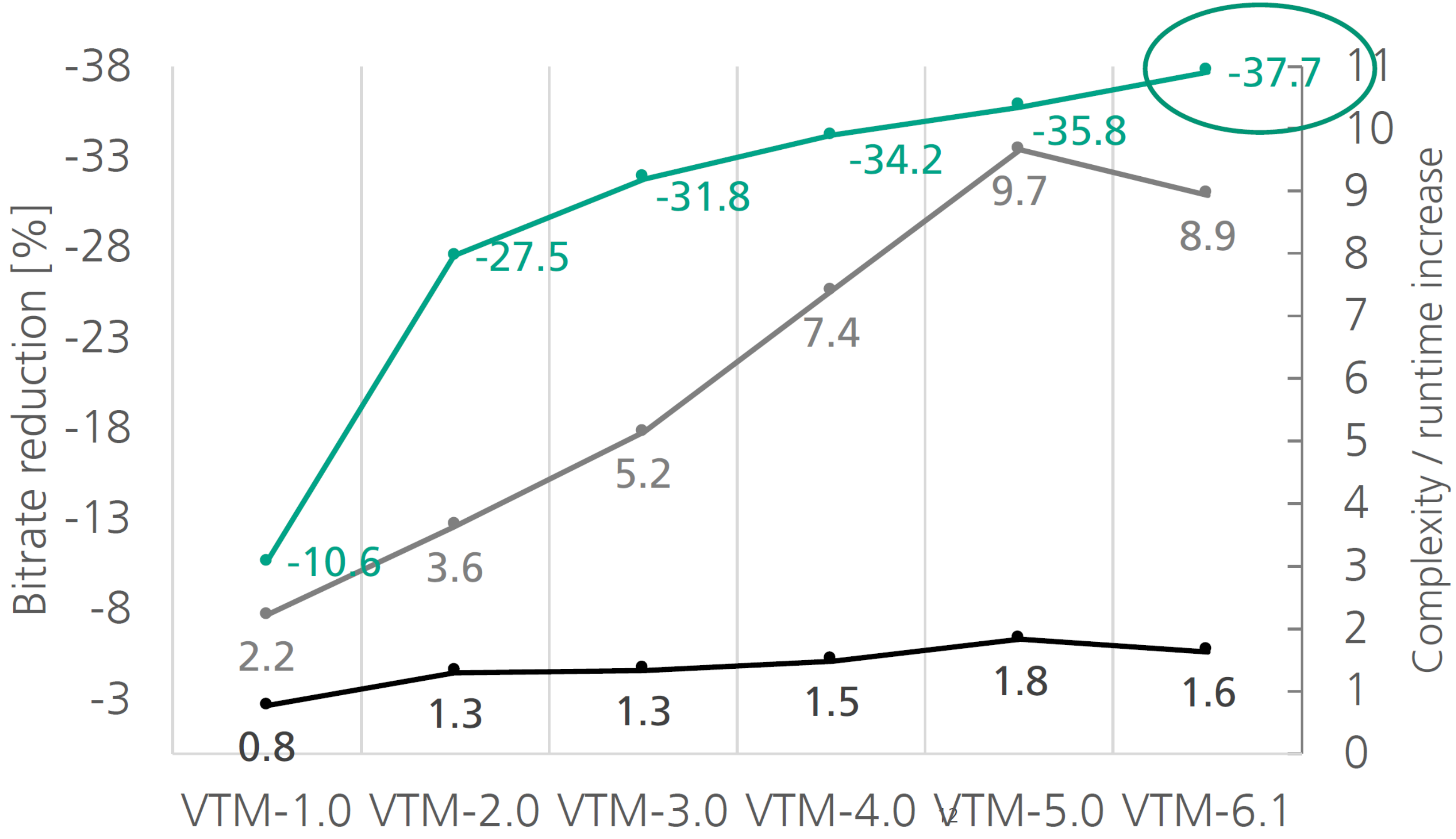
Objective performance: VVC vs. HEVC

	Bitrate saving	Encoder complexity	Decoder Complexity
3840x2160 UHD	-39%	850%	165%
1920x1080 HD	-34%	900%	160%
Lower definitions	-28%	900%	170%





VTM complexity



Same ball park as HEVC vs. AVC

Subjective gains expected to be higher (to be confirmed)

Source: Benjamin Bross « Versatile Video Coding (VVC) », ITU Workshop on "The Future of Media", Geneva, Switzerland, 8 October 2019

Subjective quality assessment (Source: INSA, JVET-O451)

- VVC significantly outperforms HEVC
  - for HD and UHD
  - for all video clips

Resolution	BD-rate (PSNR)	BD-rate (VMAF)	BD-rate (MOS)
HD	-31.24%	-35.18%	-36%
UHD	-34.42%	-40.44%	-40%

- BD-Rate improvement consistent with those measured under the CTCs

- Current VTM close to offer 40% of bit reduction over HEVC (50% claimed, to be assessed)

VVC Versatility

- Former codecs such as HEVC used to rely on extensions and special profiles to implement enhanced features
  - 2013, jan: HEVC
  - 2013, oct: extended profiles
  - 2014, oct: Scalable HEVC (SHVC)
  - 2016, feb: Screen Content Coding extension (SCC)
- Compatibility/interoperability issues among decoder generations
- VVC will implement advanced features from the beginning, even in the main profile
  - VR 360
  - Scalability
  - SCC
- Early definition of enhanced profiles, even lossless

VVC Contenders
and
Future of the Codecs War

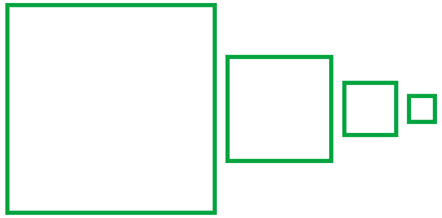
AV1: Royalty-Free Codec, Applicable for Broadcast & OTT

- AV1 (AOM Video codec 1)
  - Alliance for Open Media (AOM)
  - Interoperable and open
  - Optimized for OTT delivery
  - High Video Quality and Real-time delivery modes
  - Compression gains up to 20% w.r.t state-of-the-art
  - From low to high resolutions (including UHD, HDR, WCG)

- Classical structure +
  - new coding tools
  - additional features (Film grain synthesis, scalability, SCC)

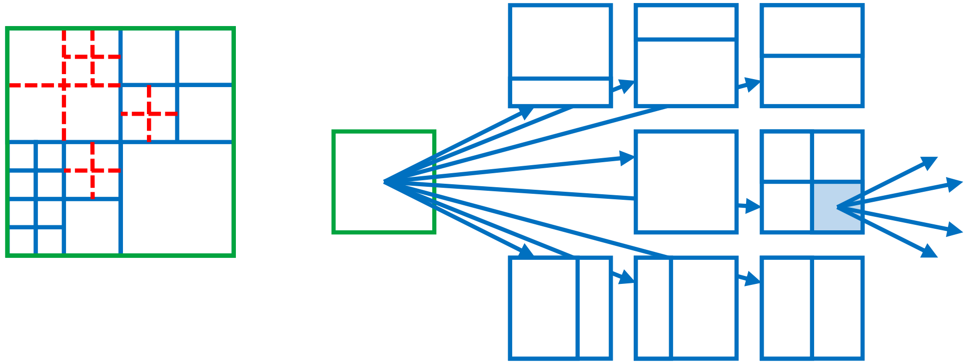
Coding Structure: HEVC vs AV1

HEVC



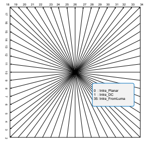
Coding Unit
64x64 to 8x8

Quadtree coding structure



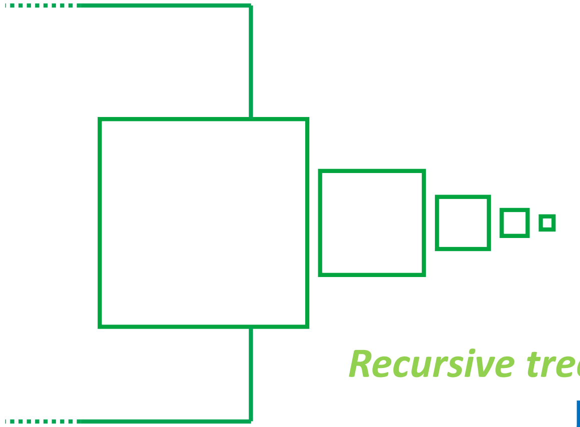
Multiples sizes/forms PUs: 64x64 to 4x4 (intra or inter for all PUs)
Square non separable TUs: 32x32 to 4x4 (2 kernel types)

33 Intra prediction directions + **2** non-directional (DC + PLANAR)



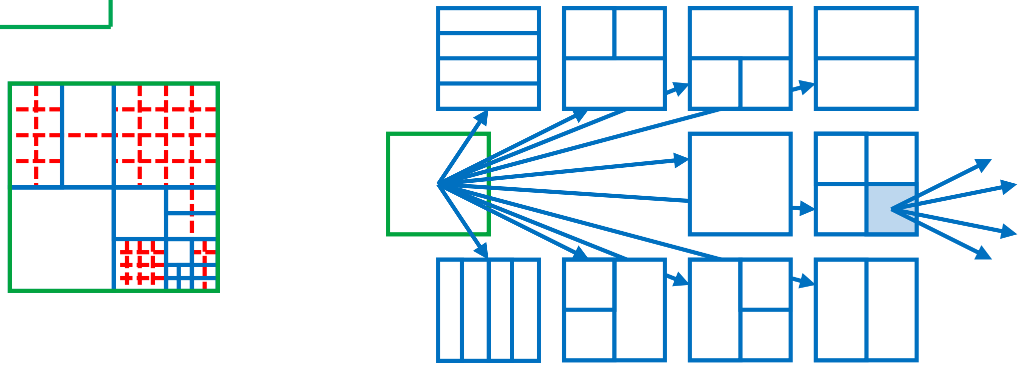
Efficient **spatio-temporal mv prediction** (Merge, AMVP)

AV1



Coding block
128x128 to 4x4

Recursive tree coding structure



Multiples sizes/forms blocks: 128x128 to 4x4 (mixing intra and inter)
Rectangular separable TUs: 64x64 to 4x4 (4 kernel types)

56 Intra prediction directions + **11** non-directional (DC + Paeth + 3 Smooth + 5 Filter + Chroma from Luma)

Efficient **spatio-temporal mv prediction** (Refmv, Newmv)

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AV1 vs. HEVC Objective Performance

- Comparable or better than HEVC overall
  - Results depending on targeted bitrate
- Higher complexity
  - Initial software 50x slower than HM
- Software framework different from usual test models
  - Highly varying evaluation results from the literature
  - many results around 10% coding gain relative to HEVC
  - Google claiming almost VVC performance

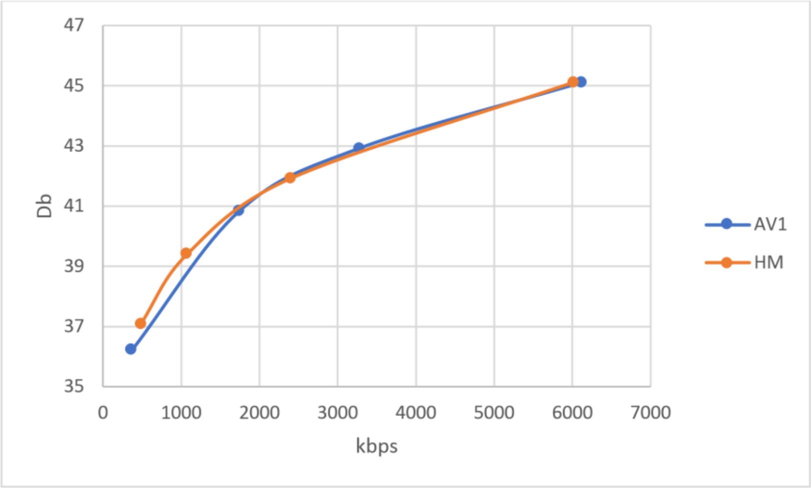


Figure 1 : Comparison between AV1 and HEVC. Kong action movie HD 1080p24 sequence, PSNR versus rate.

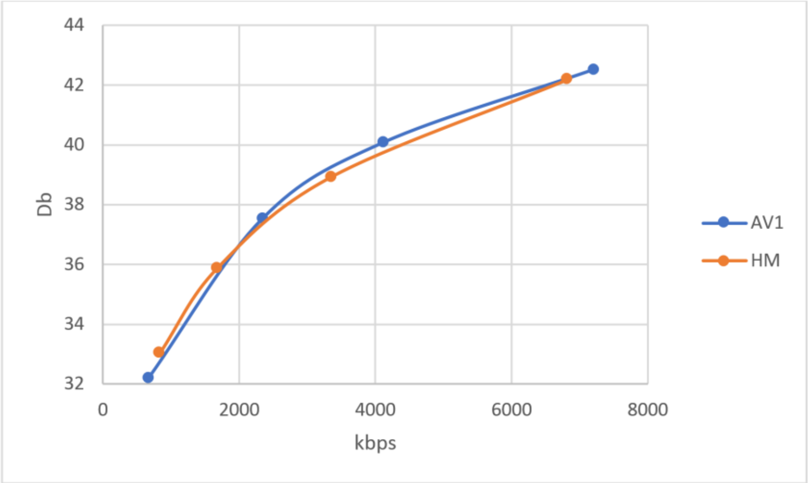


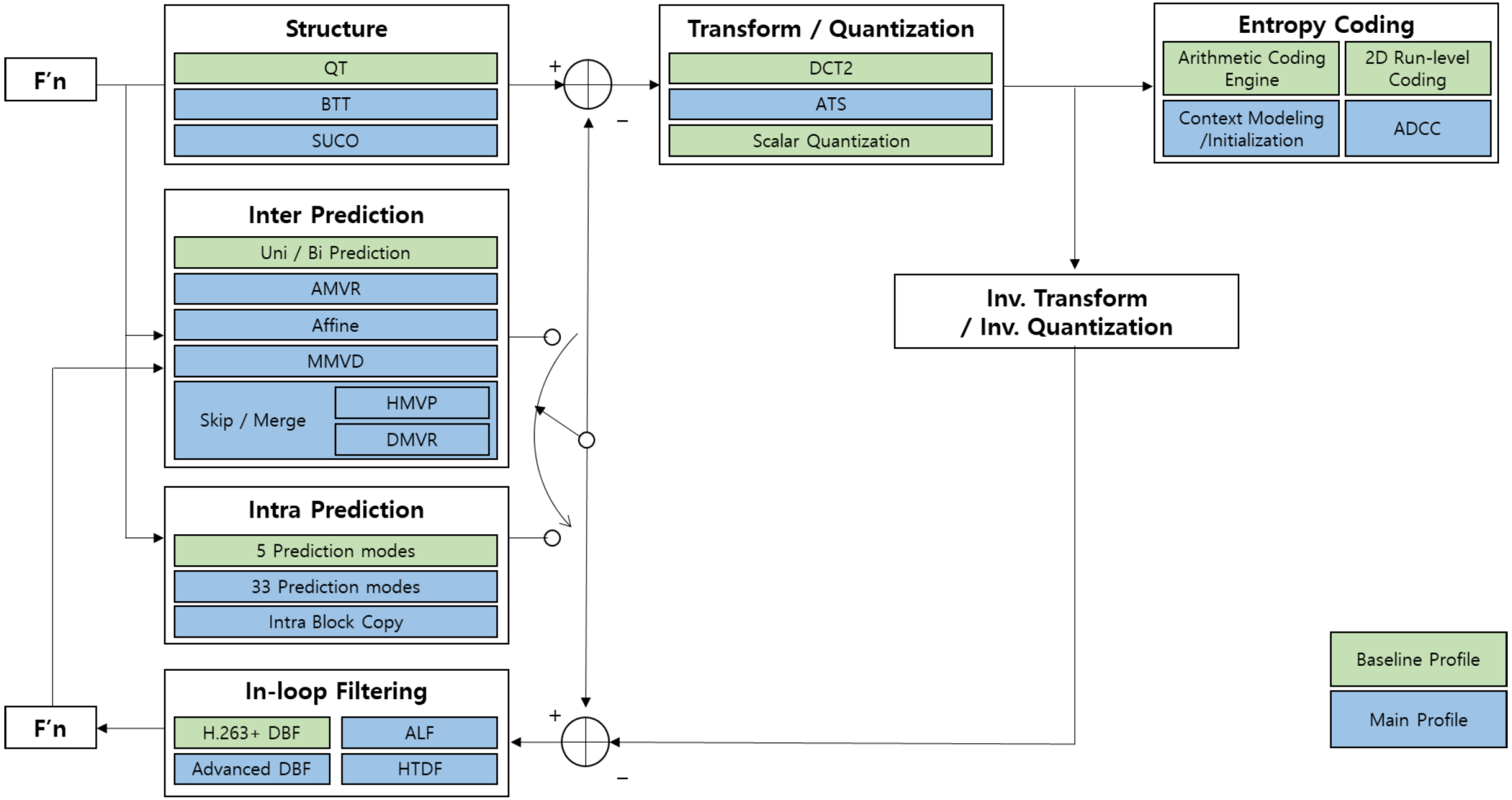
Figure 2 : Comparison between AV1 and HEVC. Netflix foodMarket TV documentary HD 720p60 sequence, PSNR versus rate.

MPEG-5 part 1: Essential Video Coding (EVC)

- Standardization effort started January 2019
- Overall goals for EVC
  - address use cases that are currently not well served by other MPEG and ITU T standards
  - Encourage the timely publication of licensing terms to allow reliable business plans to be created
  - Coding efficiency at least as good as HEVC
  - Complexity suitable for practical real time encoding
- Samsung, Huawei and Qualcomm's joint CfP response
- FDIS scheduled for April 2020 (same as VVC)
- Baseline profile
  - Only technologies more than 20 years old or submitted with a royalty free declaration
- Main profile
  - Small number of additional tools providing significant coding gains
  - Each additional Main profile tool can be switched off independently of other tools
  - Contributors encouraged to submit voluntary declarations on the timely publication of licensing terms

MPEG-5 part 1: Essential Video Coding (EVC)

- Nested Baseline/Main structure
- Some tools inherited from VVC



Source: Ken McCann « MPEG-5 Essential Video Coding (EVC) », ITU Workshop on "The Future of Media", Geneva, Switzerland, 8 October 2019

MPEG-5 part 1: Essential Video Coding (EVC)

- Baseline profile, compared to H.264/AVC JM

	BD rate	Encoding time	Decoding time
UHD	-38%	46%	117%
HD	-24,8%	39%	114%
Overall	-31,4%	42%	116%

- Main profile, compared to H.265/HEVC HM

	BD rate	Encoding time	Decoding time
UHD	-30%	413%	167%
HD	-23,1%	491%	142%
Overall	-26,5%	450%	154%

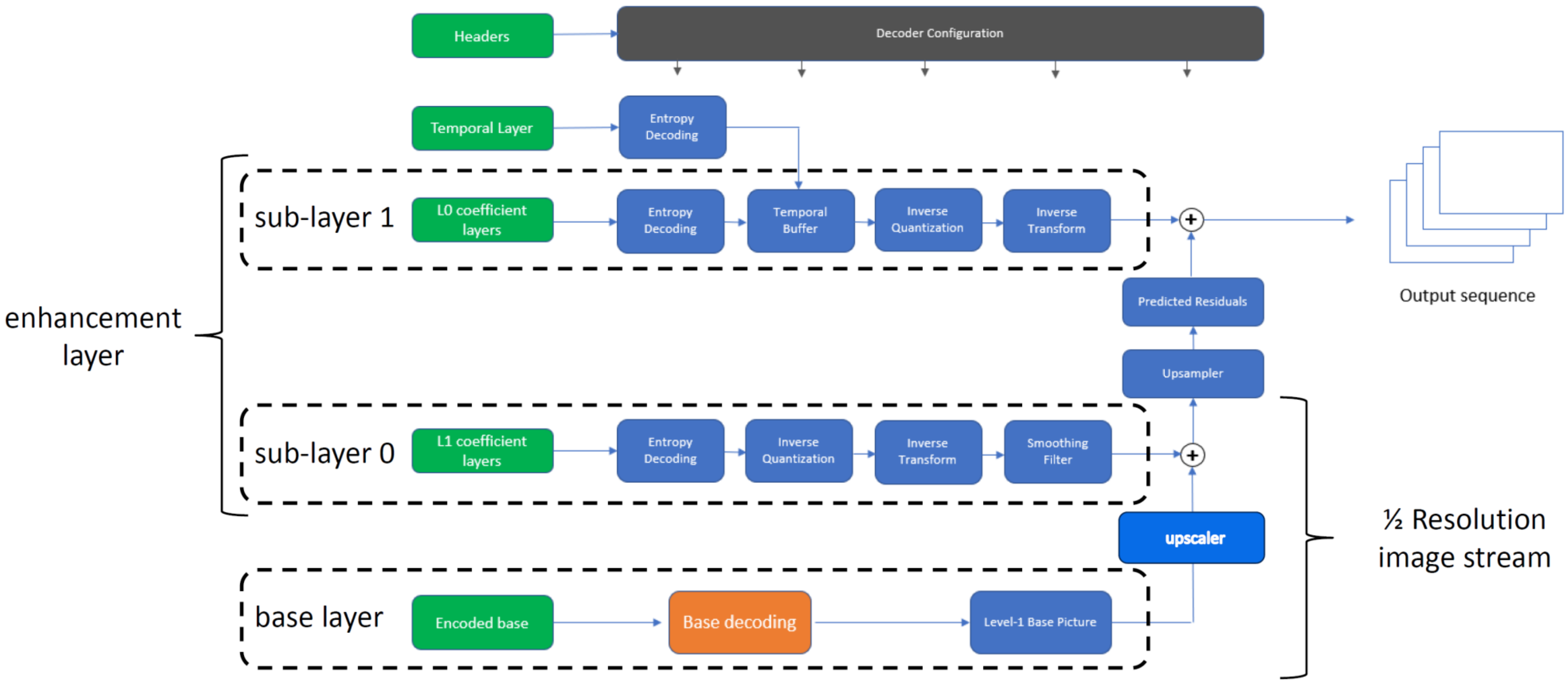
Source: MPEG

MPEG-5 part 2: Low Complexity Enhancement Video Coding (LCEVC)

- Stems from V-Nova's Perseus proprietary codec
- Taking a different approach: low complexity first
- Single proponent
  - Almost working alone until recently
  - Missing the usual group emulation and competition
- FDIS scheduled for April/July 2020
- Obvious need for a « standard stamp » from a private company
- Licensing relying on V-Nova
  - Says there will be no issues
  - Some other actors may reveal to have relevant IP

MPEG-5 part 2: Low Complexity Enhancement Video Coding (LCEVC)

- Scalable structure
  - Though not meant to output base layer
- Base layer using an existing standard
- Enhancement layers specified by LCEVC

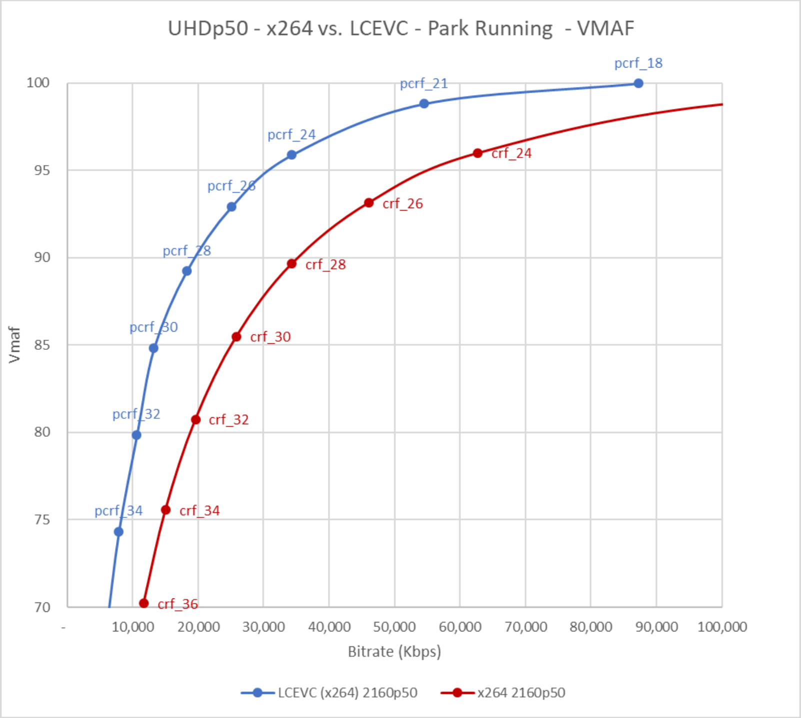


Source: Guido Meardi « Introducing MPEG-5 Part 2 LCEVC », ITU Workshop on "The Future of Media", Geneva, Switzerland, 8 October 2019

MPEG-5 part 2: Low Complexity Enhancement Video Coding (LCEVC)

- Low complexity achieved (1/4 size base layer + fast processing)
- Coding performance to be further analyzed

Proponent



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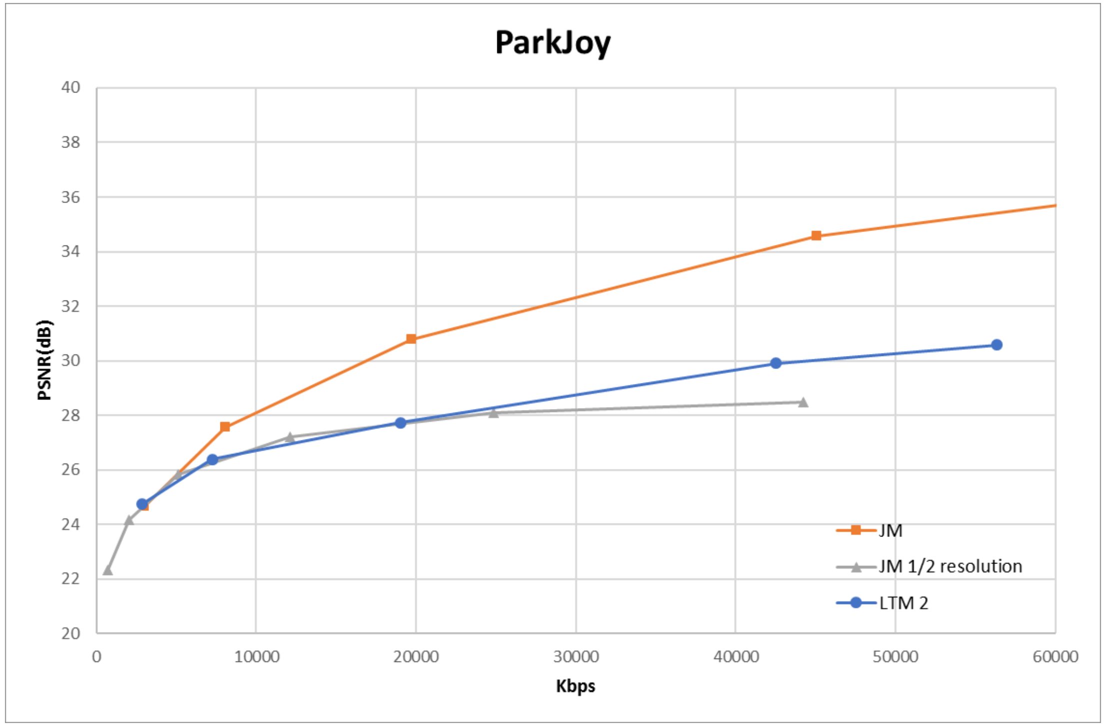

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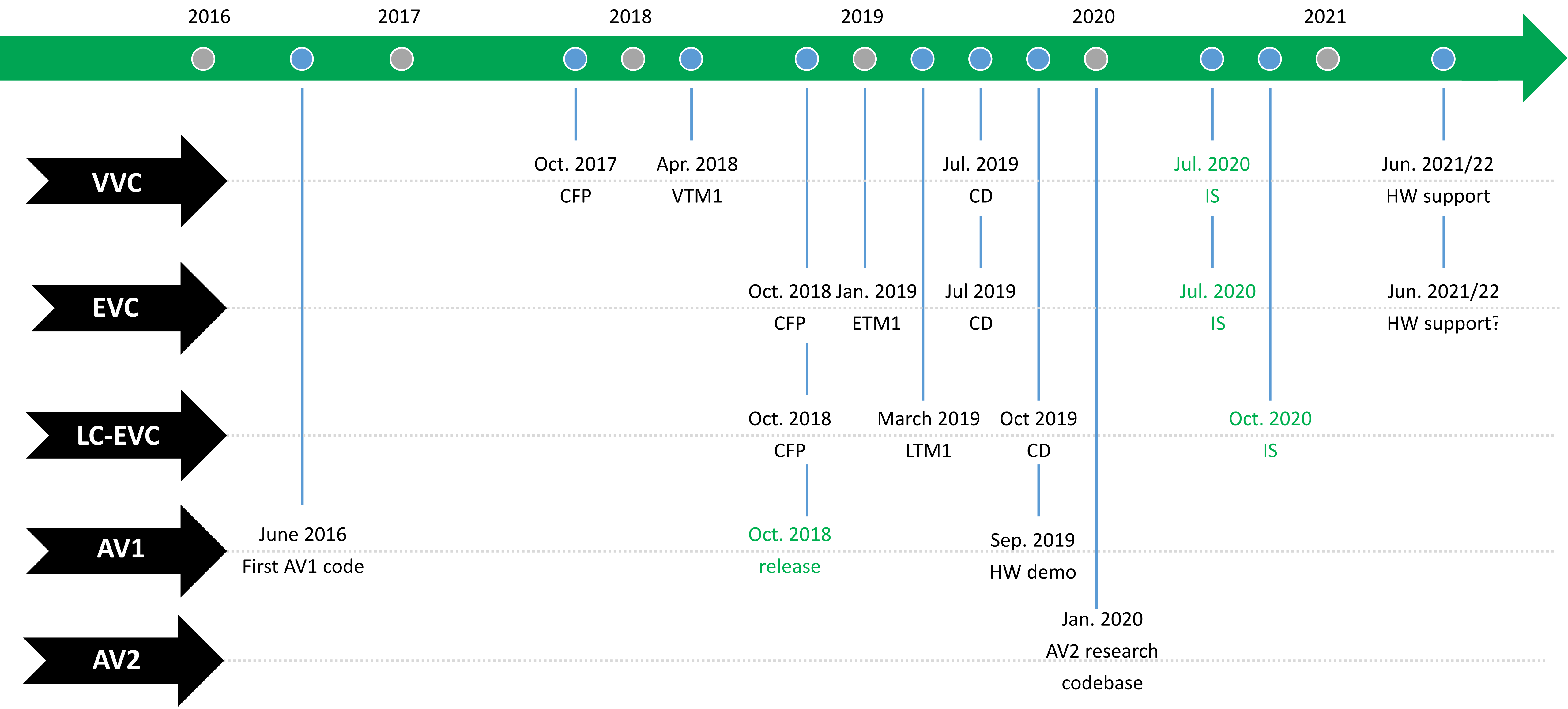
VVC, MPEG-5 EVC & LCEVC, AV1 timelines



VVC, MPEG-5 EVC & LCEVC, AV1 performances

- Reference results
  - LCEVC mismatch

  -> under investigation

Over HEVC	BD rate HD	BD rate UHD	MOS UHD	Encoding time	Decoding time
VVC	-34%	-39%	50%	875%	165%
EVC main	-23,1%	-30%	X	450%	155%

Over AVC	BD rate HD	BD rate UHD	MOS UHD	Encoding time	Decoding time
EVC bas.	-25%	-38%	X	43%	116%
LCEVC	X	-25,5%	-45,5%	41%	~40%

- JVET-O0898 (interdigital)
  - July 2019

Over HEVC	BD rate HD-UHD	Encoding time	Decoding time
VVC	-35,7%	1274%	160%
EVC main	-20,5%	474%	156%
AV1	-10,7%	493%	257%

VVC, MPEG-5, AV1 for broadcast

- Linear broadcast constraints
  - CBR
  - Real-time
  - No statmux
  - + density, controlled latency

- ATEME view
  - Current HEVC UHD live
    - -25% PSNR BD-rate compared to AVC
  - AV1:
    - current live implementation approximately -5% PSNR BD-rate compared to HEVC
  - VVC:
    - Ongoing live implementation
    - Target -25% PSNR BD-rate compared to HEVC
    - Relying on AI to handle part of the complexity
  - EVC main
    - No implementation yet
  - EVC baseline
    - No implementation yet
  - LCEVC: out of scope for now, under investigation

Over AVC

Live Broadcast	HD 2020	HD 2023
EVC baseline	-	15%
HEVC	**25%**	**30-35%**
AV1	~25+%	~30-35%
EVC main	-	35-40%
VVC	0-5%	45-50%

With progress of AI mastery, all codecs will improve!

Future of the codecs war

High-end codecs	VVC Versatile Video Coding	best performing codec Also most complex Versatility can make a difference (RPR, SCC, sub-pictures) Maturity in the ecosystem is unquestionable
	EVC Main	Could be a good contender to VVC performance/complexity-wise Success may depend on the royalties of VVC
	AV1	Released 2 years before, hardware available Even if royalty free, it is a different kind in the ecosystem
Low end codecs	EVC Baseline	Could be a worthy successor of AVC on low cost use cases
	LCEVC	Unusual strategy and coding performance/complexity trade-off could go on high end side, if proven worthy on the most recent codecs Terms of use not so clear

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