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HIGH EFFICIENCY VIDEO CODING (HEVC)

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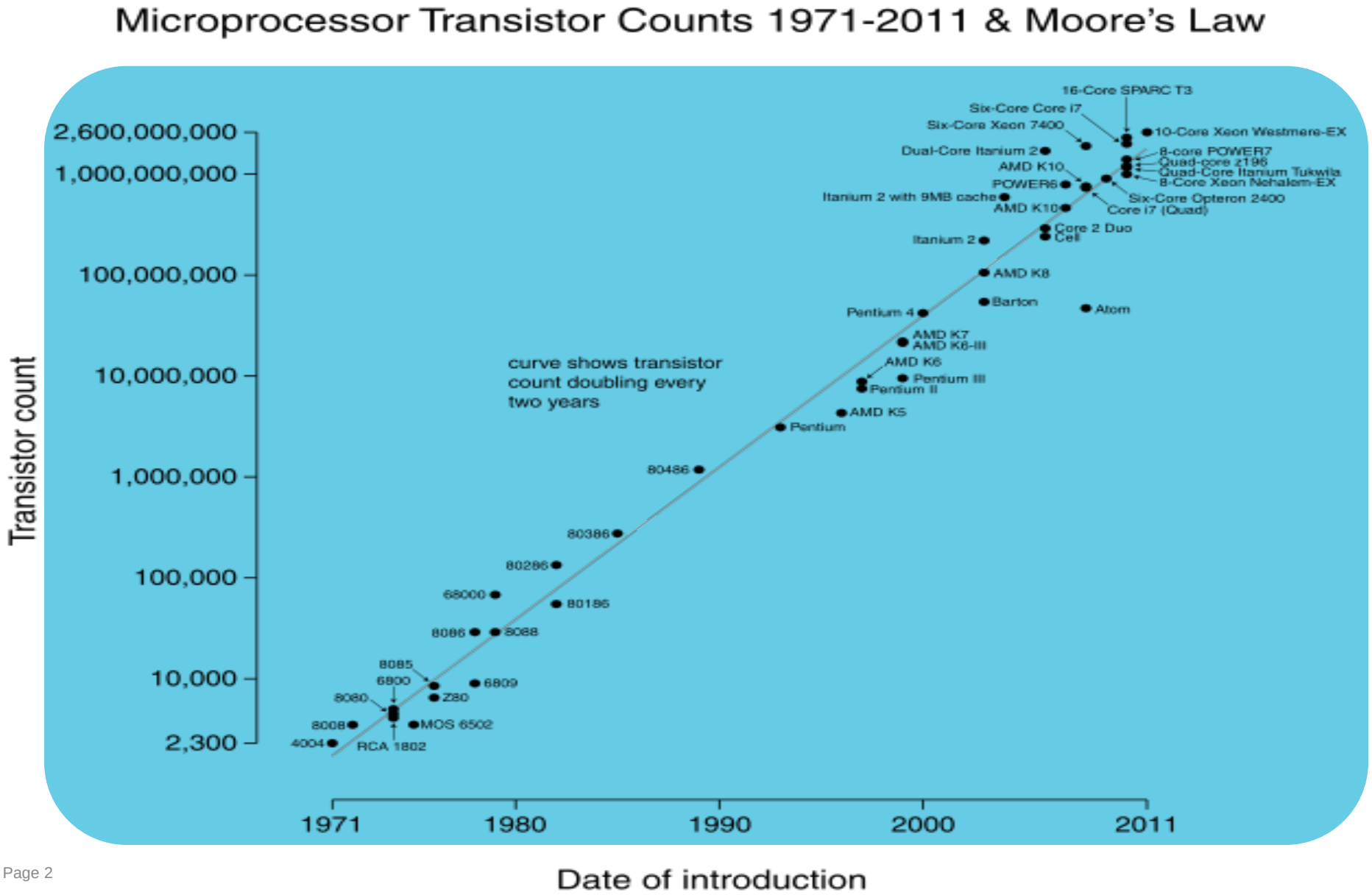
MOORE'S LAW


Microprocessor Transistor Counts 1971-2011 & Moore's Law
Transistor count
2,600,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
2,300
curve shows transistor count doubling every two years
16-Core SPARC T3
Six-Core Core i7
Six-Core Xeon 7400
10-Core Xeon Westmere-EX
Dual-Core Itanium 2
8-core POWER7
Quad-core z196
AMD K10
Quad-Core Itanium Tukwila
POWER6
8-Core Xeon Nehalem-EX
Itanium 2 with 9MB cache
Six-Core Opteron 2400
AMD K10
Core i7 (Quad)
Core 2 Duo
Cell
Itanium 2
AMD K8
Barton
Atom
Pentium 4
AMD K7
AMD K6-III
AMD K6
Pentium III
Pentium II
AMD K5
Pentium
80486
80386
80286
68000
80186
8086
8088
8085
6800
6809
8080
Z80
8008
MOS 6502
4004
RCA 1802
1971
1980
1990
2000
2011
Date of introduction

TRANSLATED TO MEMORY COST …

Year	Cost for 1 GigaByte = 1,000 MBytes (Storage for 2 Scanned File Cabinets)	Cost for 1 TeraByte = 1,000 GBytes (Storage for 2,000 Scanned File Cabinets)
1992	1,000.00	1,000,000.00
1993	625.00	625,000.00
1994	390.63	390,625.00
1995	244.14	244,140.63
1996	152.59	152,587.89
1997	95.37	95,367.43
1998	59.60	59,604.64
1999	37.25	37,252.90
2000	23.28	23,283.06
2001	14.55	14,551.92
2002	9.09	9,094.95
2003	5.68	5,684.34
2004	3.55	3,552.71
2005	2.22	2,220.45
2006	1.39	1,387.78
2007	0.87	867.36
2008	0.54	542.10
2009	0.34	338.81
2010	0.21	211.76
2011	0.13	132.35
2012	0.08	82.72
2013	0.05	51.70
2014	0.03	32.31
2015	0.02	20.19

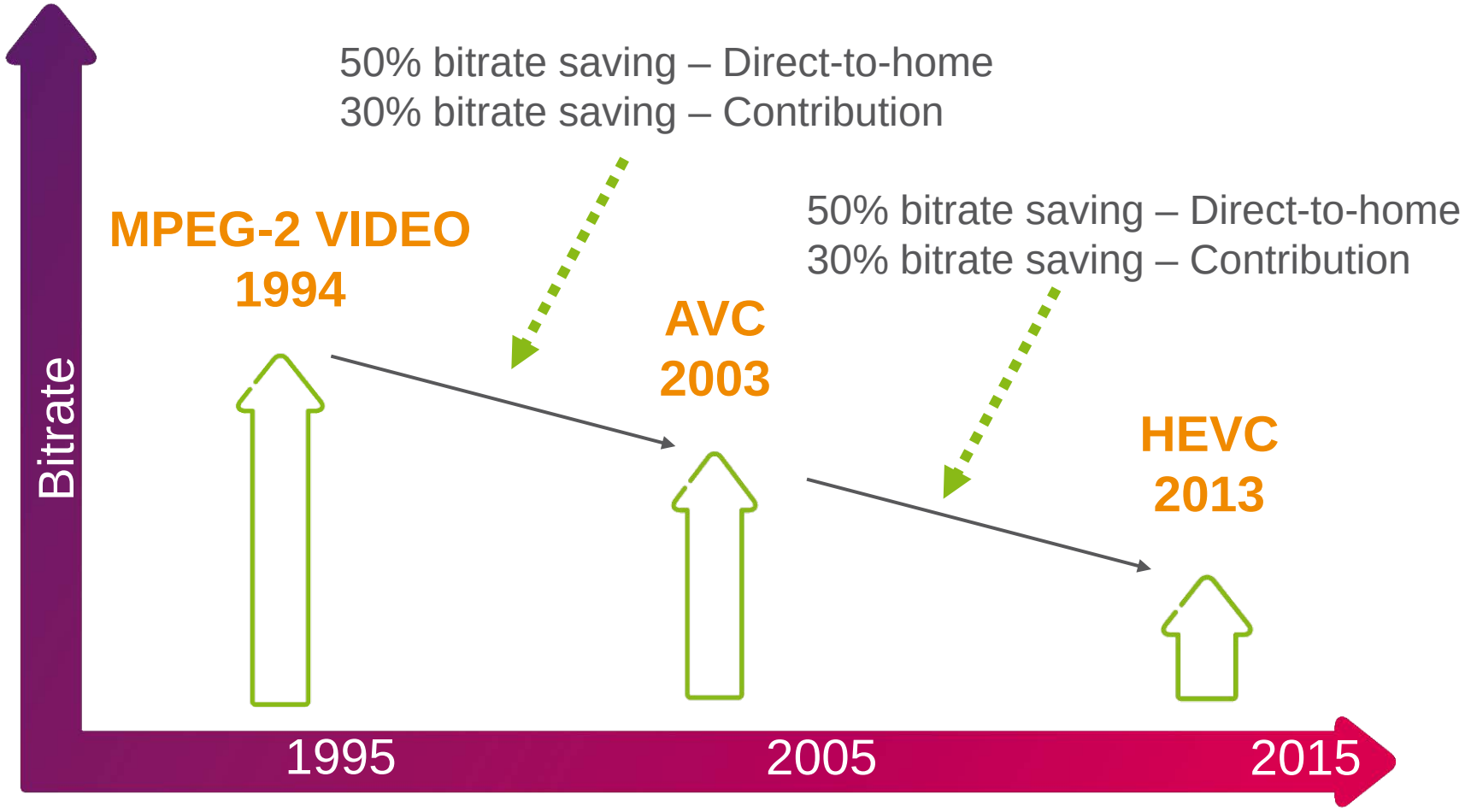
VIDEO COMPRESSION EVOLUTION

- Need a higher performing and more bandwidth efficient video compression standard, to enable the launch of new services and support the explosion of available content
- Made possible by increased computing power available in consumer devices
- Moore's Law also enables the use of more advanced and complex encoding/decoding techniques
- Profiles are defined with different performance / complexity tradeoffs to enable different, economically viable applications

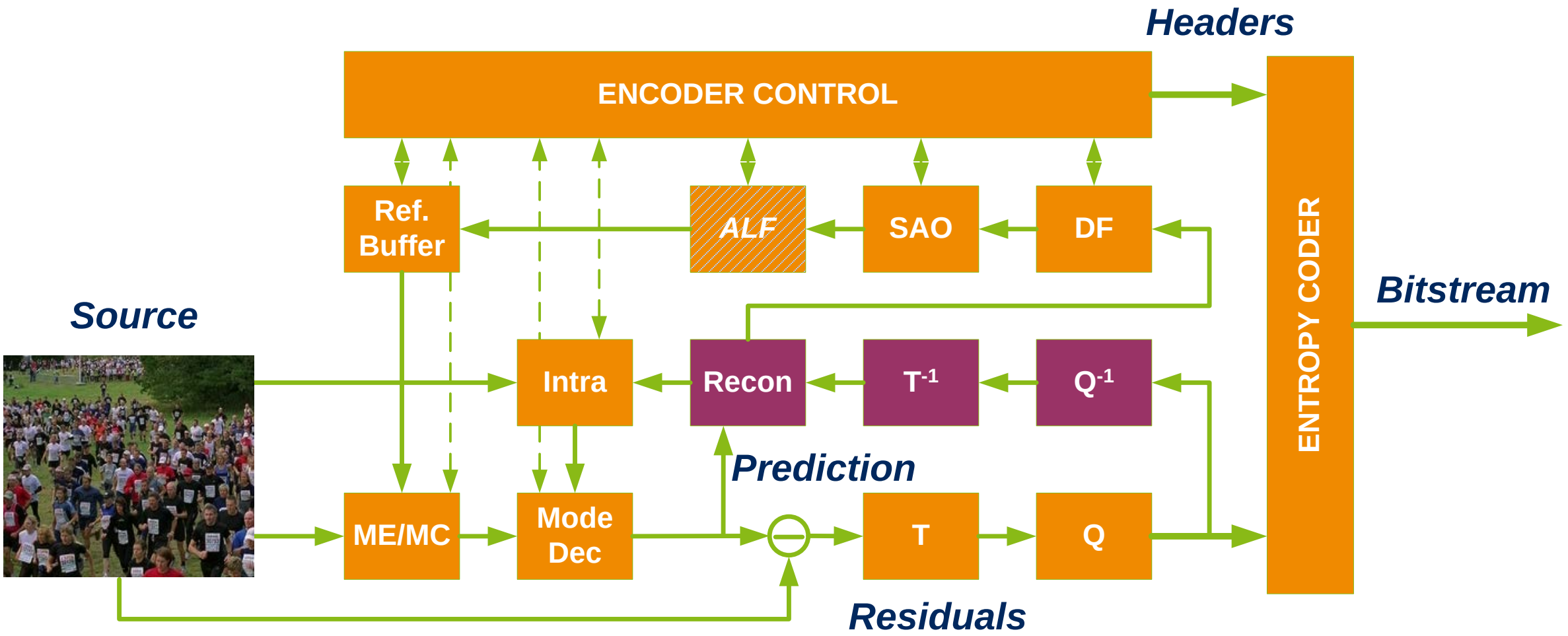
HIGH EFFICIENCY VIDEO CODING

- A **Joint Collaborative Team on Video Coding** (JCT-VC) of MPEG & VCEG
- Standards nomenclature: **ISO/IEC 23008-2** MPEG-H Part 2 and ITU-T Rec. **H.265**
- **"Version 1"** for Consumer/Direct-to-Home applications
  - 3 profiles, including Main and Main 10
  - Finalized January 2013
- **Range Extensions (RExt)** support Content Acquisition & Exchange
  - 15 profiles including Main 4:2:2 10, Main 4:2:2 12, Main 4:4:4 10, Main 4:4:4 12
  - Finalized April 2014
- **Scalable High-efficiency Video Coding (SHVC)** supports layered coding
  - Includes temporal, spatial, quality, color gamut scalability; 8-bit and 10-bit profiles
  - Finalized July 2014
- **Screen Content Coding (SCC)**
  - Expected completion February 2016
- **High Dynamic Range (HDR) & Wider Color Gamut (WCG)** exploration
  - Call for Evidence expected in February 2015 – Goal: single layer coding efficiency of >=15%

COMPRESSION BANDWIDTH EFFICIENCY TRENDS



HEVC ENCODER



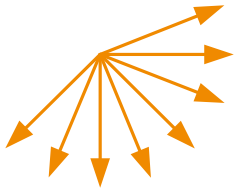
HIGH LEVEL TOOL COMPARISON

AVC

16X16 block size

Various Inter partitions down to 4x4

9 intra modes

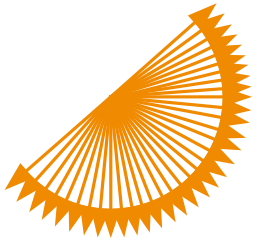


8x8 and 4x4 transform sizes

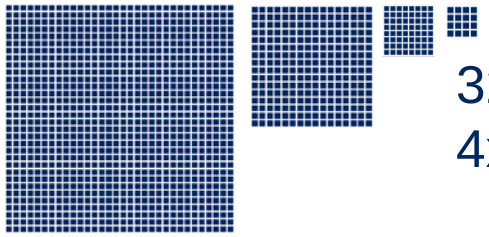
HEVC

64x64 block size

Hierarchical quad-tree partitioning down to 8x8 + 4x4 Transform Units



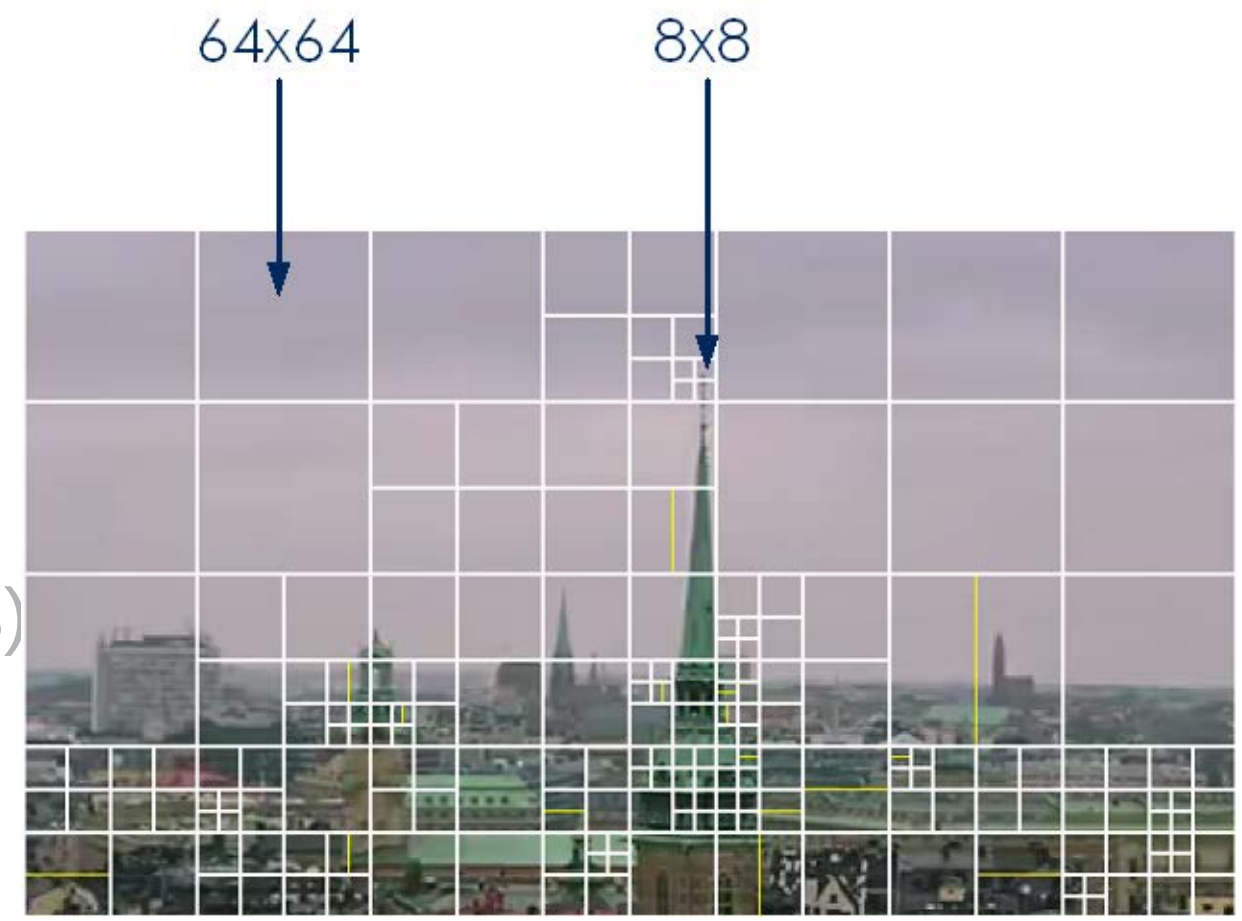
35 intra modes



32x32, 16x16, 8x8 and 4x4 transform sizes

CODING TREE

- **Coding Tree is collection of Coding Units (CU) – CU size 64x64 to 8x8**
- CUs can have independent coding modes
- Further partitioning using Prediction Units (Motion Vectors)
- Independent Transform Tree partitioning from 32x32 to 4x4



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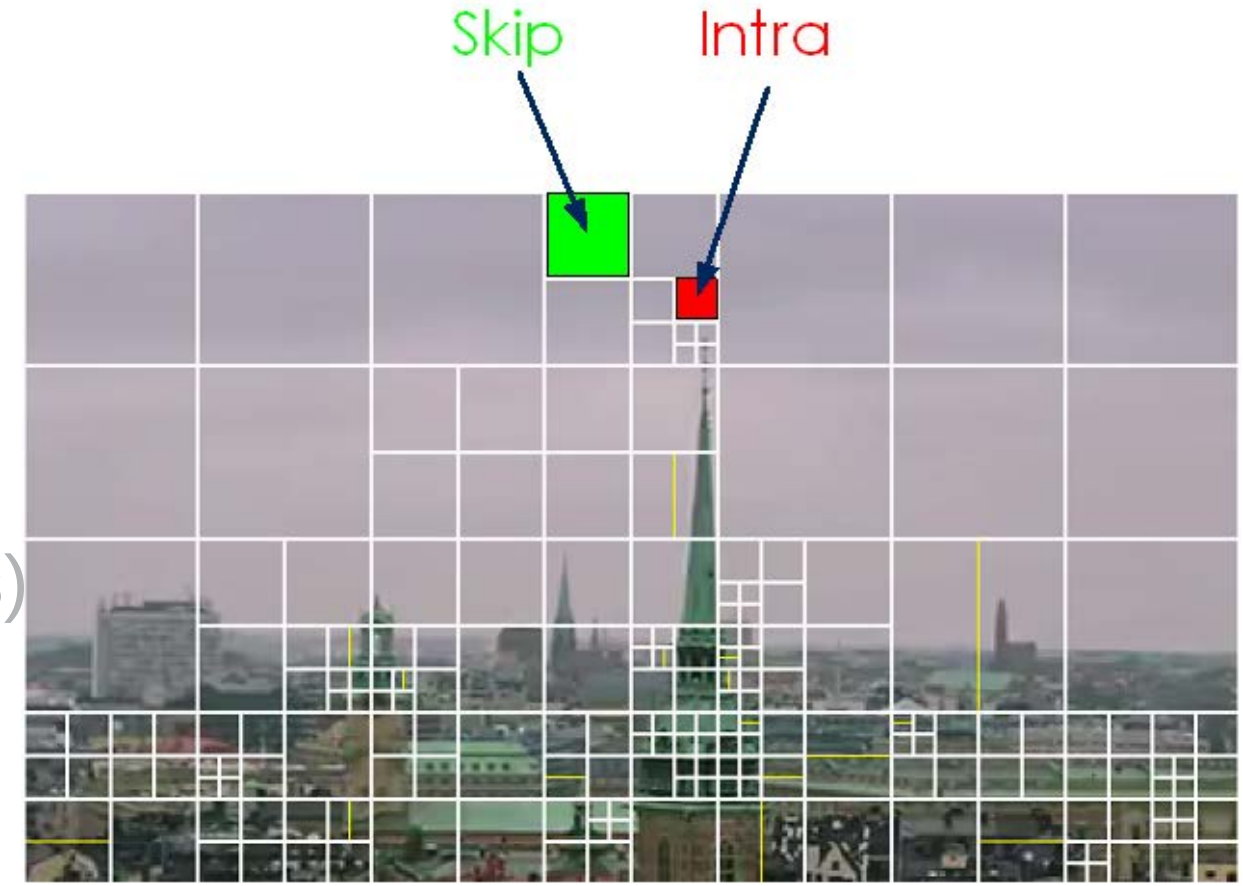

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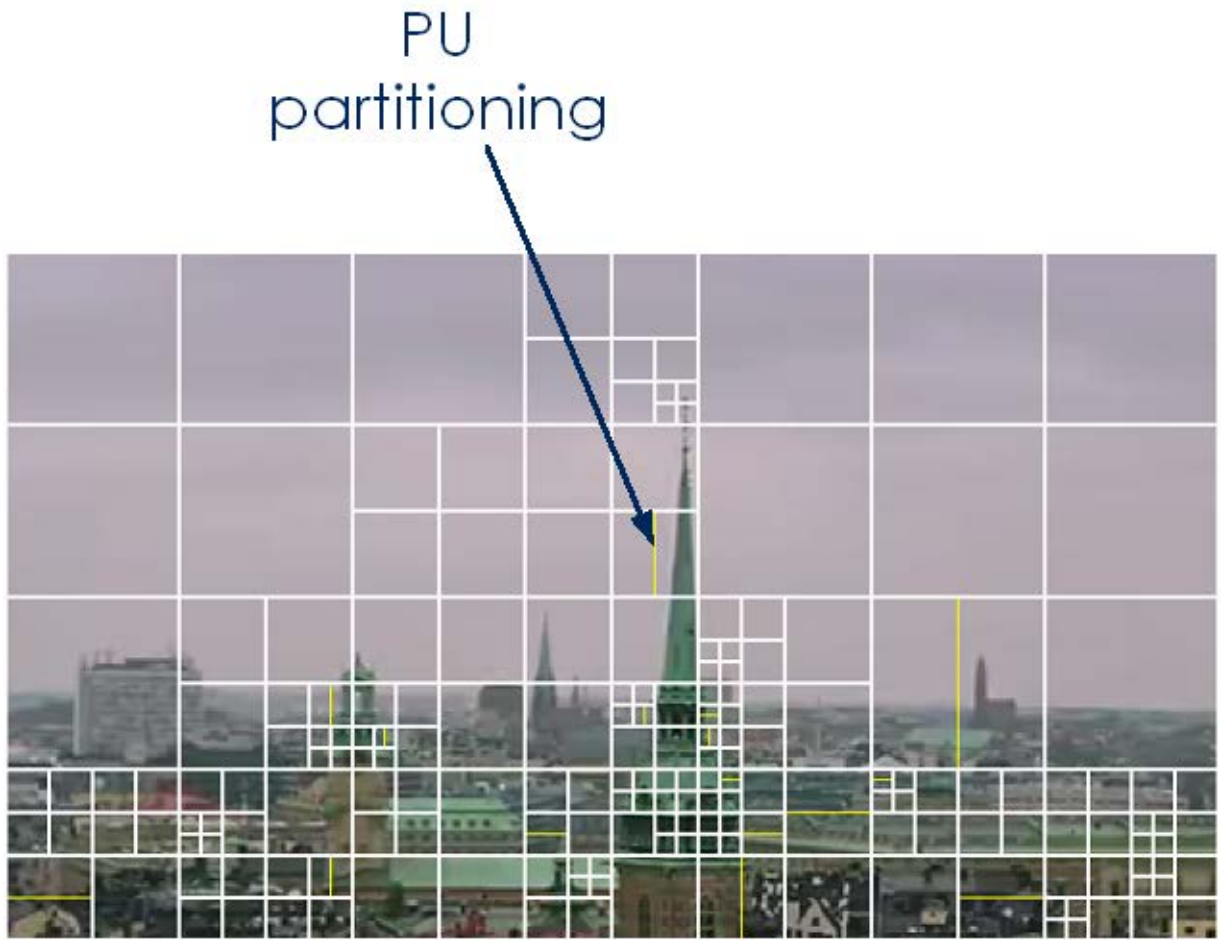

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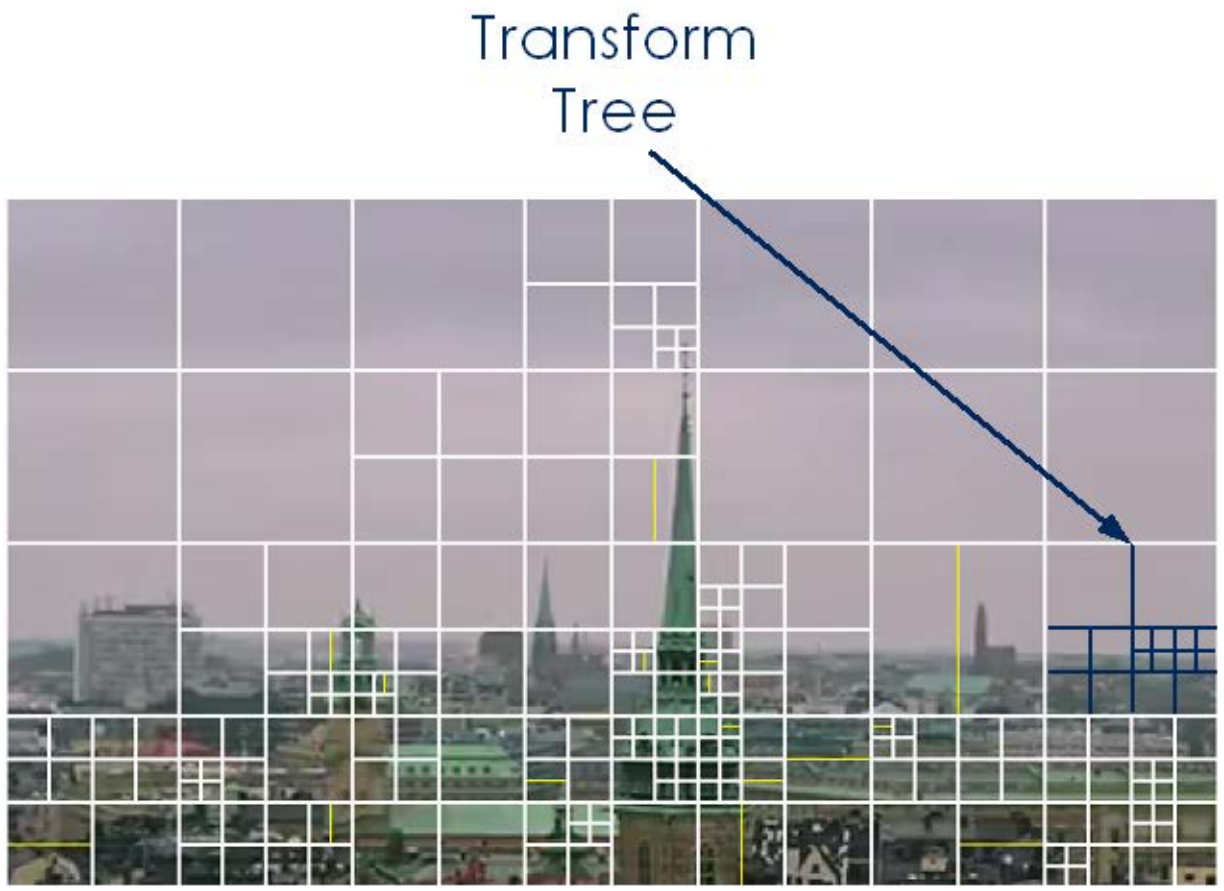
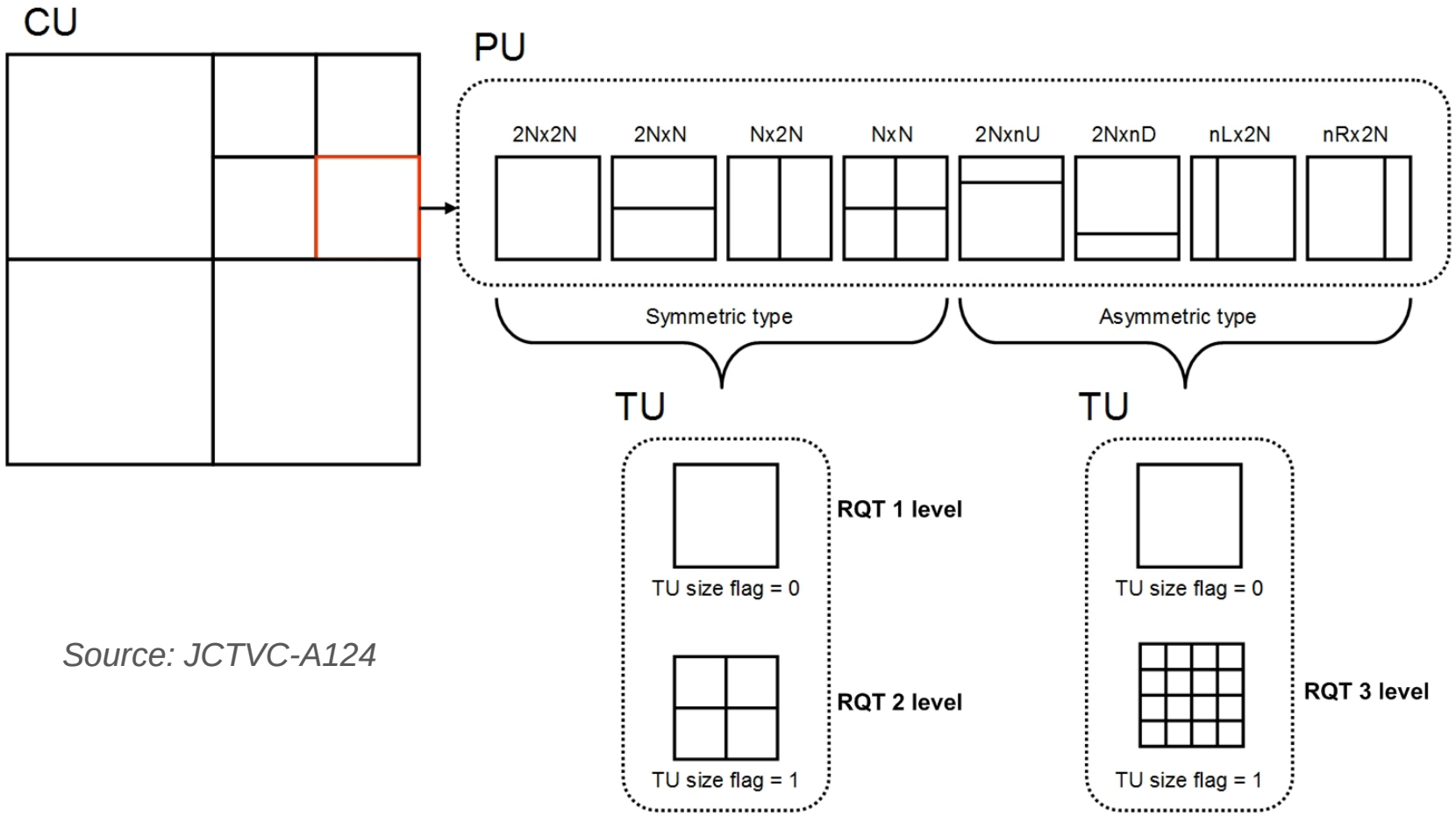


CODING UNITS: PREDICTION & TRANSFORM UNITS



Source: JCTVC-A124

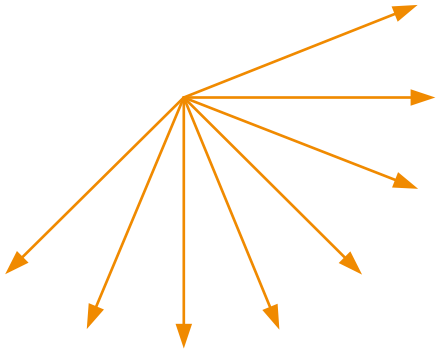
Separation of prediction and transform structures allows more flexible and efficient coding of video under various conditions and resolutions

HEVC TOOLS – INTRA PREDICTION

AVC

DC +

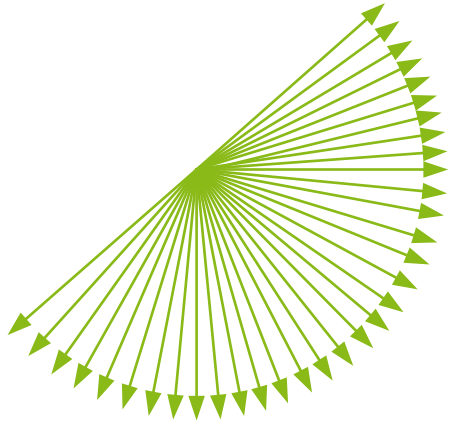
8 directional modes

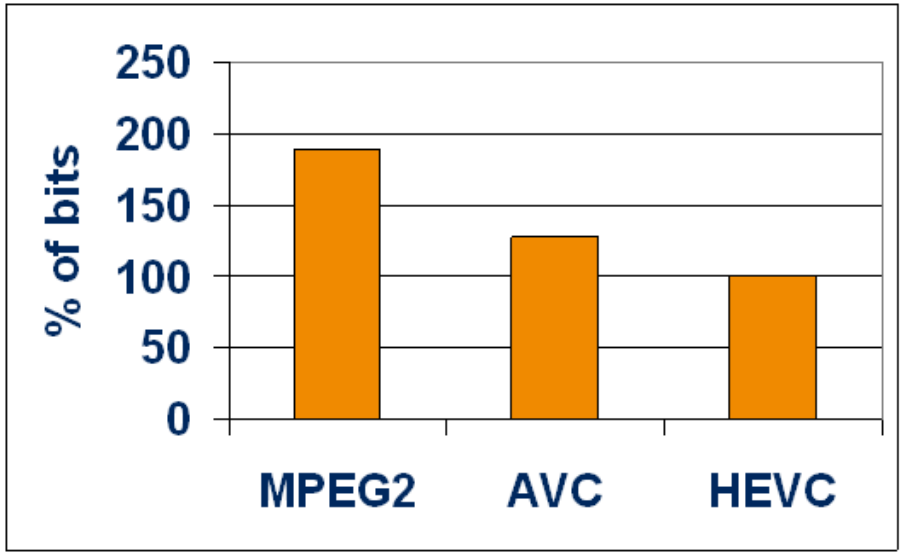


HEVC

DC + Planar +

33 directional modes





HEVC TOOLS – IN-LOOP FILTERS

- Deblocking Filter
  - Similar to AVC deblocking filter but does not filter 4x4 block edges
- Sample Adaptive Offset (SAO) Filter
  - Calculates edge and band offsets signaled to decoder
  - Offsets added to reconstructed pixels
  - SAO is not restricted to block boundaries

No In-loop filters

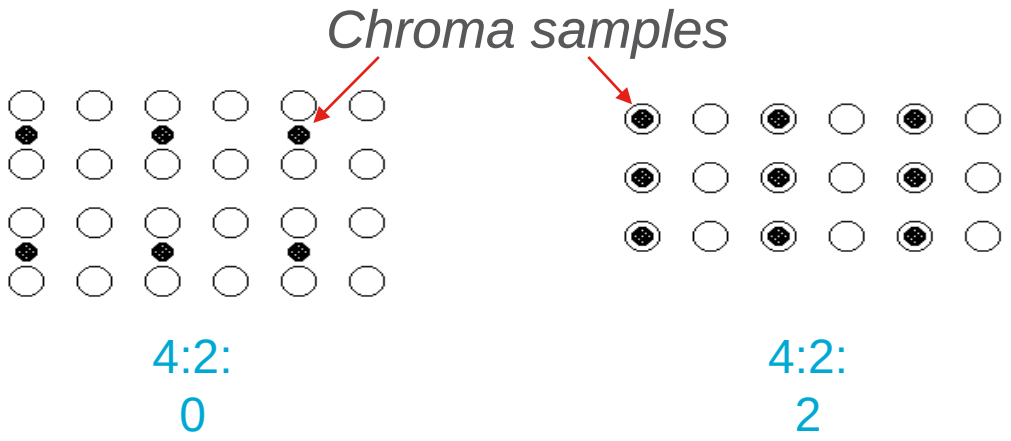
Deblocking filter + SAO filter

TOOL COMPARISON: AVC vs HEVC

AVC High Profile	HEVC Main Profile
16x16 Macroblock	Coding Unit quadtree structure, 64x64 down to 8x8
Partitions 16x16 to 4x4 square + non-square (inter)	Prediction Units, 64x64 to 8x8 square + non-square (inter) + asymmetric (inter)
8x8 and 4x4 transforms	Transform Units, 32x32 to 4x4, 4x4 skip
Intra prediction (8 directions + DC)	Intra prediction (33 directions + DC + planar)
Inter prediction luma 6-tap + 2-tap, to ¼ pel	Inter prediction luma 8-tap, to ¼ pel
Inter prediction chroma bi-linear interpolation	Inter prediction chroma 4-tap. to 1/8 pel
Motion vector prediction	Advanced motion vector prediction (spatial + temporal)
In-loop deblocking filter	In-loop deblocking filter & Sample Adaptive Offset (SAO) filter
CABAC or CAVLC	CABAC using parallel operations

CABAC = Context Adaptive Binary Arithmetic Coding
CAVLC = Context Adaptive Variable Length Coding

CONTRIBUTION: 4:2:2 VS. 4:2:0



Chroma rate = ¼ Luma rate

Saves **50% bandwidth**

Chroma rate = ½ Luma rate

Saves **33% bandwidth**

4:2:0 production flow

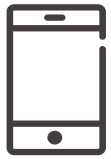
4:2:2 production flow

Keying with 4:2:0

Source: http://www.dv.com/dv/magazine/2006/November/DV0611.hdvout.fig4.jpg

CONFLICTING GOALS FOR RANGE EXTENSIONS (REXT)

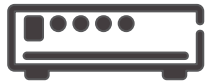
Consumer



Low bitrates

Reuse HEVC v1 implementations

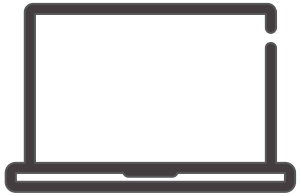
Professional



High bitrates

Coding gains more important than hardware reuse

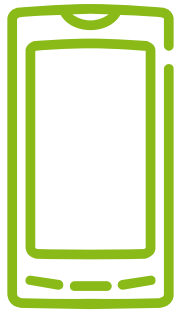
Mixed Content



Consumer applications

New tools for mixed 4:2:0 & 4:4:4 coding

HEVC USE CASES



Video over LTE

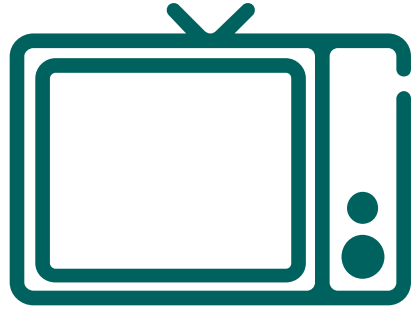
- Expensive bandwidth
- Increasing demand for content on the move

Multi-screen

- More HD
- More screens

DSNG & Contribution

- More HD
- Expensive bandwidth

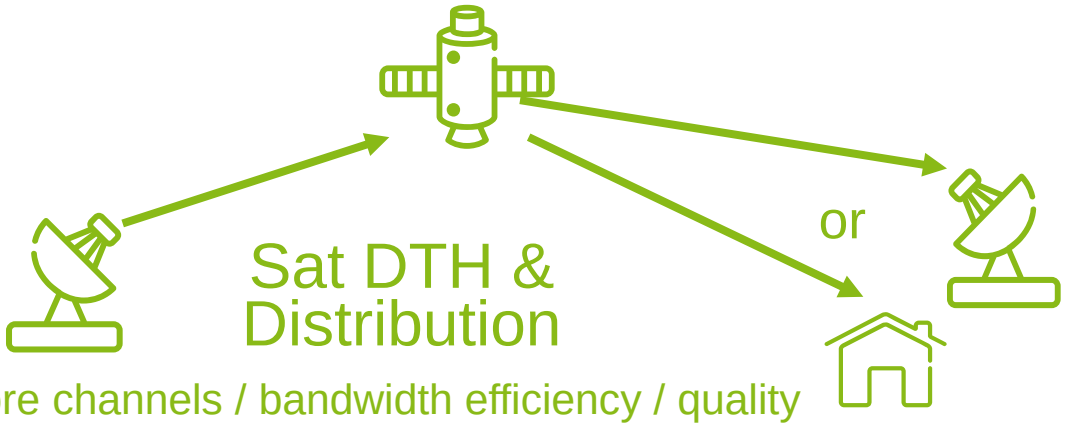


UHDTV

- High bitrate need
- Must be “true” UHDTV
- VoD enablement

- Deeper reach / more HD channels
- More channels per QAM
- Better picture quality

- More channels / better picture quality
- FOBTV & ATSC 3.0: Fixed + Mobile scalable coding



- More channels / bandwidth efficiency / quality

HEVC IMPLEMENTATION DEPENDS ON MARKET SEGMENT NEEDS

- Different market segments have different needs
  - **Software on COTS** hardware for offline, mobile and OTT/multiscreen
  - **Software on purpose-built** hardware for more demanding applications
- Product rollouts will depend on market segment readiness and will happen at different times
  - Encoders, decoders, production equipment, licensing, set-top boxes

*COTS = Commodity Off-The-Shelf

A BIT MORE ABOUT UHDTV

In context of broadcast television, “4K TV” is UHDTV Level 1 (UHD-1) or 4K UHDTV

› UHDTV is not just about more pixels

› To be an immersive viewing experience, it’s about “better” pixels …

- Higher frame rate
- Higher dynamic range
- Wider color gamut
- Deeper sample bit depths

WHAT FORMAT WILL INDUSTRY SETTLE ON FOR 4K UHDTV?

True 4K UHDTV HEVC requires 80x more processing power than HD AVC

SDTV HDTV 4K UHDTV 24-30fps 8b True 4K UHDTV 60fps 10b

… and this discussion has not included the audio delivery format for UHDTV!

HEVC POTENTIAL - DIRECT-TO-HOME
FOR SIMILAR PICTURE QUALITY

	MPEG-2 Video	AVC	HEVC
SD	3 - 5 Mbps	1.8 - 3 Mbps	1 - 1.8 Mbps
HD	10 - 18 Mbps	5 - 9 Mbps	2.5 - 4.5 Mbps
4K UHDTV (2160p60 10b)	N/A	N/A	8 – 15 Mbps* 15 – 25 Mbps**

For typical PQ comparisons

****For higher PQ expectations***

As with all bitrate projections, these ranges are subject to PQ expectations & content complexity

HEVC POTENTIAL - CONTRIBUTION
FOR SIMILAR PICTURE QUALITY

	MPEG-2 Video 4:2:2 8b	AVC 4:2:2 10b	HEVC 4:2:2 10b
HD	35 - 60 Mbps	23 - 40 Mbps	17 - 30 Mbps**
4K UHDTV (2160p60)	N/A	100 - 160 Mbps*	55 - 100 Mbps**

4 x 1080p60

****Estimated; HEVC Range Extension Main 4:2:2 10 Profile still under evaluation***

As with all bitrate projections, these ranges are subject to PQ expectations & content complexity

HEVC SUMMARY

- HEVC is an exciting new standardized codec that greatly has improved bandwidth efficiency
  - ½ the bitrate of AVC
  - ¼ the bitrate of MPEG-2 Video
- For Contribution/Studio applications, HEVC Range Extensions (REext)
  - Expands upon HEVC v1 (consumer/direct-to-home)
  - Profiles include support for 4:2:2, 4:4:4, Intra coded only, 10-bit, 12-bit
- HEVC roll-out will occur at different times for different market segments
  - Both software running on COTS hardware and purpose-built hardware will be used
  - Some segments require mature ecosystem to be in place (+ regulatory)
    - New set-top boxes / TV receivers → new HEVC chipsets
  - For legacy, requires significant bitrate savings for ROI
  - First segments, 2014: LTE Broadcast and Internet “Over-the-Top” (multi-screen)
  - 2015 & later: Linear Direct-to-Home and Contribution

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