MANIPULATING UHD VIDEO TRAFFIC

invention | collaboration | contribution

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Outline

- The UHD buzz
  - What is UHD?
- The UHD traffic
  - Handling UHD with HEVC
  - Handling UHD with SHVC
- Beyond HEVC video compression

The UHD buzz

- UHD, or Ultra High Definition, is the ***new buzz*** in the industry
  - CES 2013 and NAB 2013
- Japan plans 4K broadcasting in 2014 - FIFA World Cup
- 8K broadcasting planned in 2020
- Sony's affordable 4K UHD TV and media hub
  - 55in at $4999 and 65in at $5999

UHD product announcements

DISPLAYS

SAMSUNG

LG Life's Good

TOSHIBA Leading Innovation

SEIKI

SONY make.believe

ViewSonic See the difference.

SHARP

BROADCASTERS

BBC

comcast

ESPN

NHK

REAL TIME 4K ENCODER/DECODERS

harmonic REDEFINING VIDEO DELIVERY

QUALCOMM®

ateme

BROADCOM

INDUSTRY CONSORTIUM

ATSC ADVANCED TELEVISION SYSTEMS COMMITTEE

HDMI™ HIGH DEFINITION MULTIMEDIA INTERFACE

Blu-ray Disc™

CAMERAS

RED DIGITAL CINEMA

ASTRO

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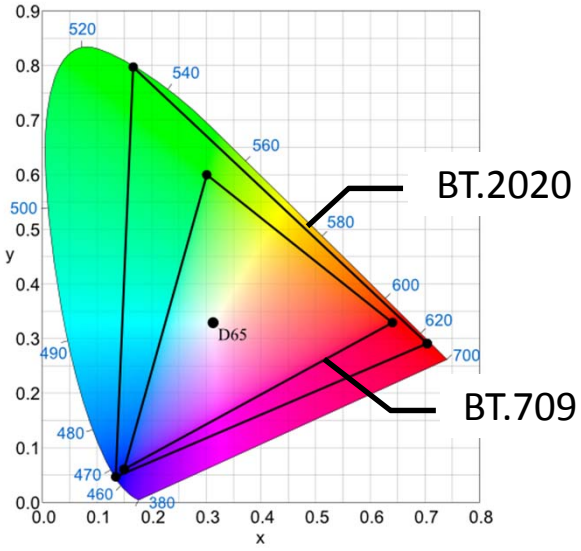
What is UHD?

UHD is defined by ITU-R BT.2020

- Higher resolution: 4Kx2K, 8Kx4K
- Higher frame rate: up to 120fps
- Higher bit depth: 10- and 12-bit
- Wider color gamut



		High Definition	Ultra High Definition
ITU-R BT series		BT.709-5 (part 2)	BT.2020
Spatial		1920x1080	7680x4320, 3840x2160
Temporal	Frame rate	60, 50, 30, 25, 24	120, 60, 50, 30, 25, 24
	Scan	Progressive, interlaced	Progressive
Primary colors	Red primary	(0.640, 0.300)	(0.708, 0.292)
	Green primary	(0.150, 0.330)	(0.170, 0.797)
	Blue primary	(0.600, 0.060)	(0.131, 0.046)
	White point	(0.3127, 0.3290) (D65)	
Coding format		8- and 10-bit	10- and 12-bit

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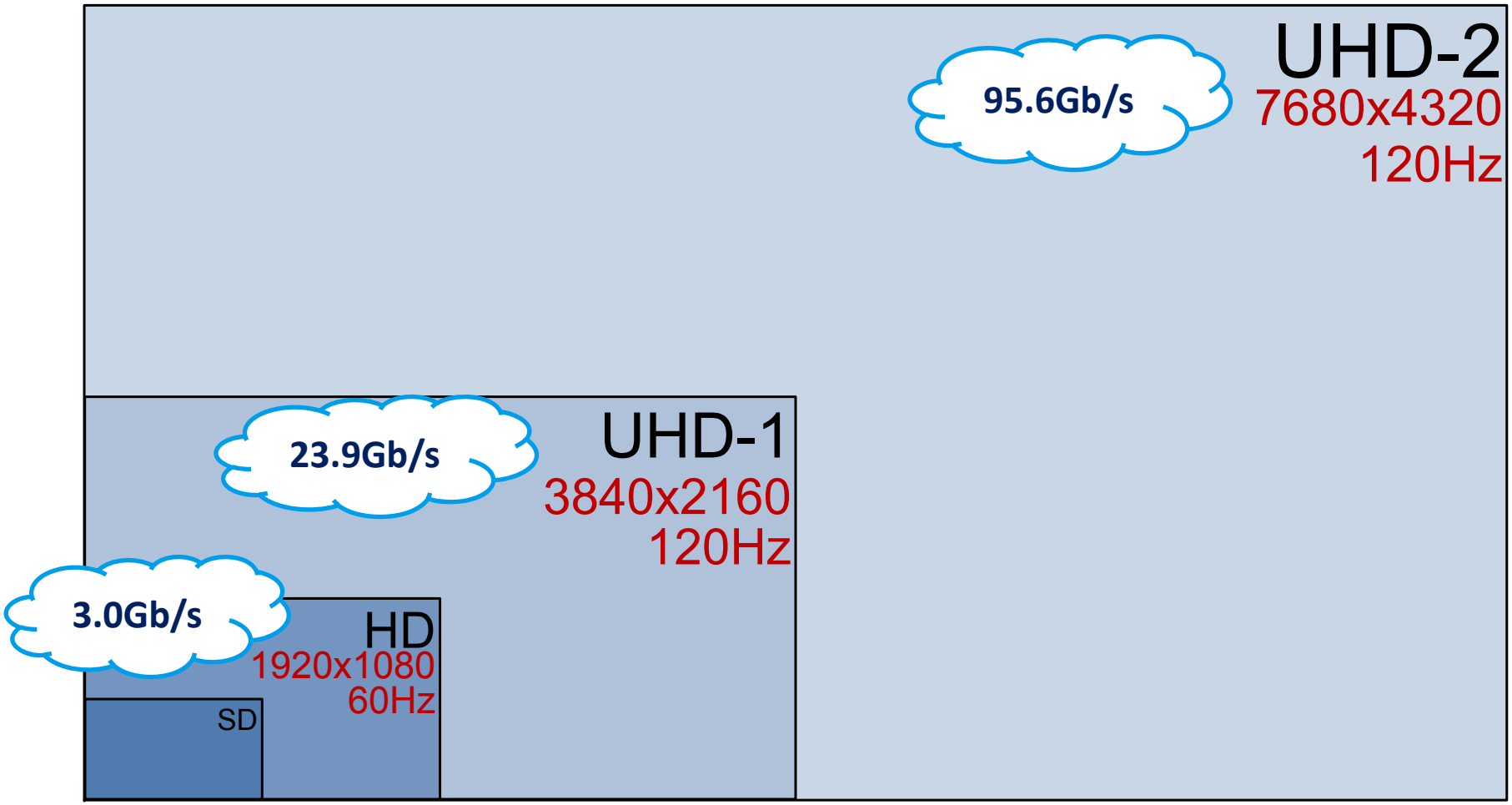
In raw form, UHD signals carry massive data



* Assuming 8 bits per sample per color component in RGB/YCbCr 4:4:4

The need for HDMI 2.0

Display

UHD TV

To support UHD-1 @ 60 Hz, we need *HDMI 2.0*, with expected throughput of 18Gb/s

HDMI cable

Decoding

Streaming box

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Distributing UHD video using HEVC/H.265

- UHD video distribution requires more efficient video compression algorithms
- The High Efficiency Video Coding standard was finalized by the JCT-VC committee in Jan 2013
  - ISO/IEC/MPEG: MPEG-H Part 2 (23008-2) HEVC
  - ITU-T: H.265
- Roughly half the bit-rate at the ***same subjective quality*** compared to H.264/AVC
- HEVC delivers higher performance gain for higher resolution video

HEVC Performance: Subjective Quality based

DSIS (Double Stimulus Impairment Scale) according to ITU-R BT.500

Sequences		Bit rate savings at same MOS (HEVC vs. H.264/AVC HP)	
1080p	BQTerrace	63.1%	
	BasketballDrive	66.6%	
	Kimono	55.2%	**57%**
	ParkScene	49.7%	
	Cactus	50.2%	
WVGA (720x480)	BQMall	41.6%	
	BasketballDrill	44.9%	**40%**
	PartyScene	29.8%	
	RaceHorses	42.7%	
Average		**49.3%**	

More gain for higher resolution

Notes:
- Entertainment applications
- Random Access config
- HEVC settings: HM5.0, QP = {31, 34, 37, 40}
- H.264/AVC: JM18.2* (imp encoder control), QP = {27, 30, 33, 34}

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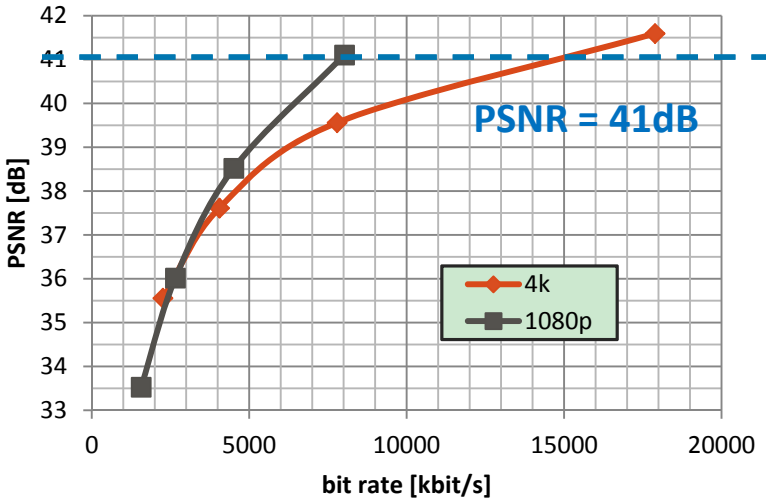
HEVC performance for different resolution sources

- 3GPP DASH is evaluating HEVC performance across different resolutions
- Compared to H.264/AVC, HEVC consistently achieves higher performance gain as resolution increases

	S4-130672	S4-130708
1080p	42.2%	40.4%
720p	34.9%	35.8%
480p	31.9%	34.1%
240p	27.1%	30.9%
Average	**33.3%**	**35.3%**

Test settings:
- 5 original 1080p sequences were downsampled at various ratios
- Random Access configurations (open and closed GOP)
- PSNR based measurement

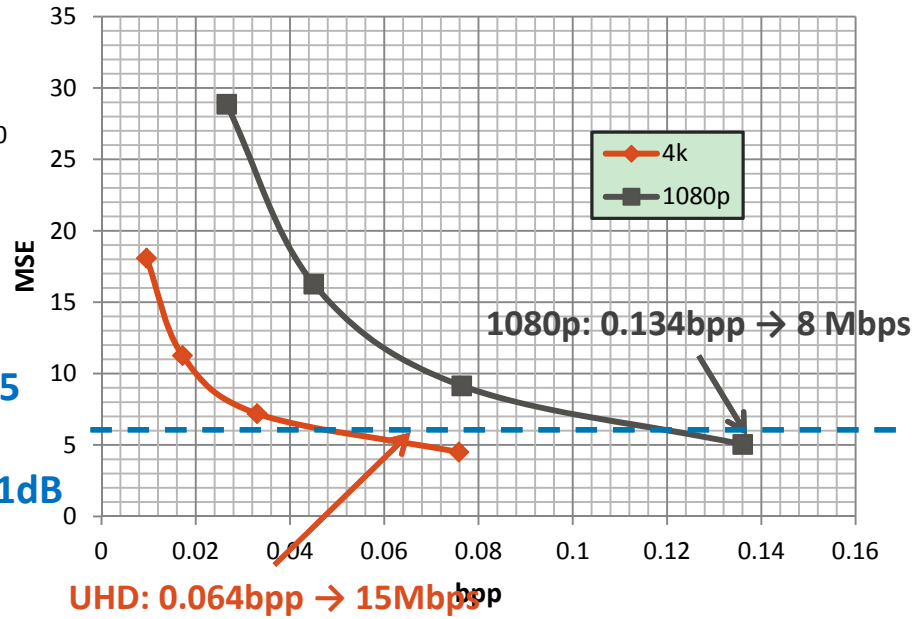
UHD signal is easier to compress



Test sequences: Traffic, 3940x2048, and 1920x1024, 30fps

Normalized R-D curve

$$r = R/(F \times W \times H)$$



MSE = 5
↕
PSNR = 41dB

Although UHD has more pixels, the bit cost per pixel is lower

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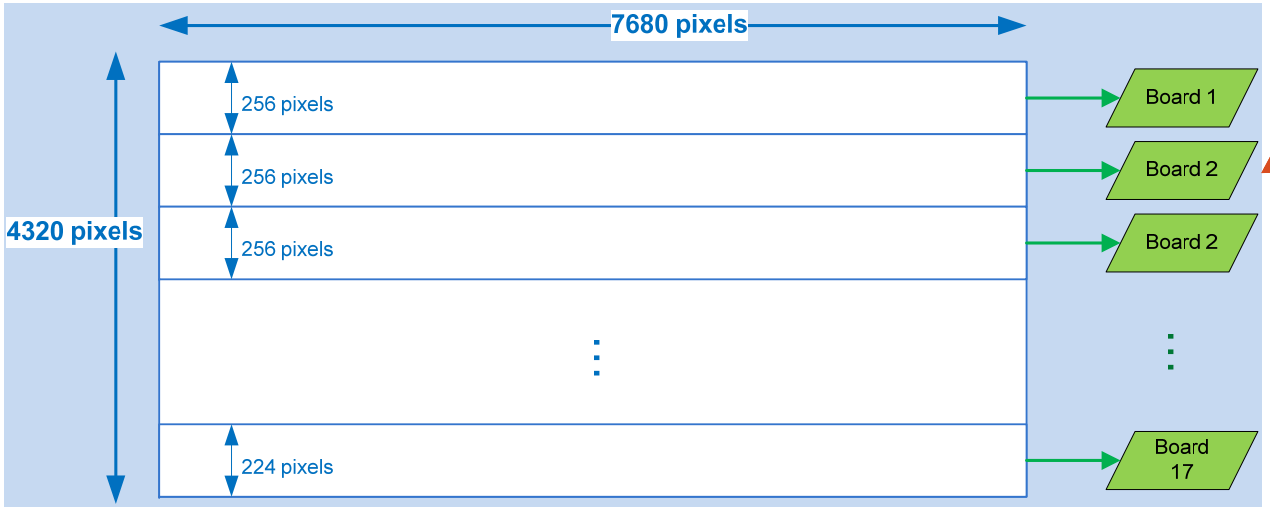
Handling UHD with HEVC

- HEVC offers significantly enhanced compression capabilities
- UHD bit cost is “cheaper per pixel”
- Recent UHD broadcasting trials using HEVC:
  - UHD-1 @ 60fps: 35Mbps
  - UHD-2 @ 60fps: 85Mbps



Real time HEVC encoding: dividing 1 picture into 17 strips

HEVC encoder will continue to mature, bringing down bit rate

- YouTube 1080p video coded using H.264:
  - Standard quality: 8Mbps
  - high quality: 50Mbps

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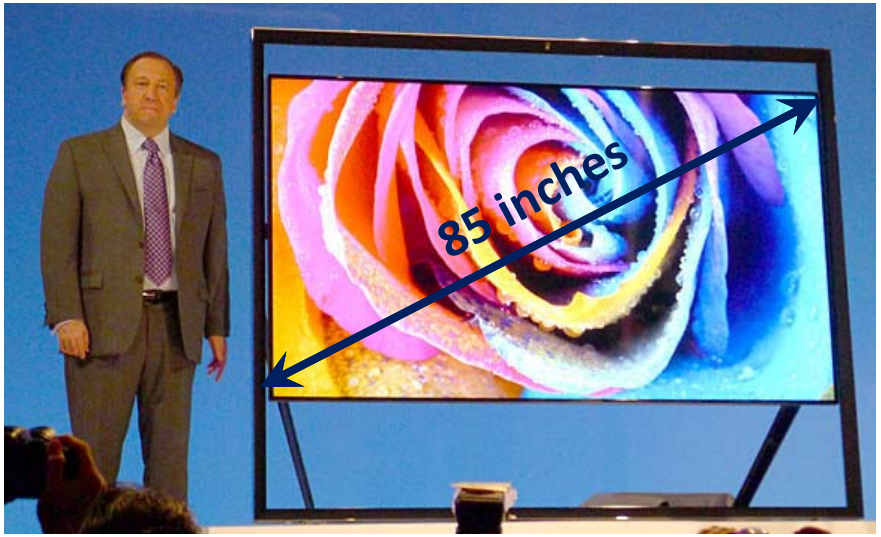
The case for scalable video coding

- To have the "***look out the window***" viewing experience, UHD displays have large screen sizes
  - Samsung 4K TV 85S9: 85"
  - ASUS 4K monitor: 39"



- Meanwhile, 1080p will continue to be the dominant format for portable devices

Co-existence of UHD and HD → the case for scalable video coding

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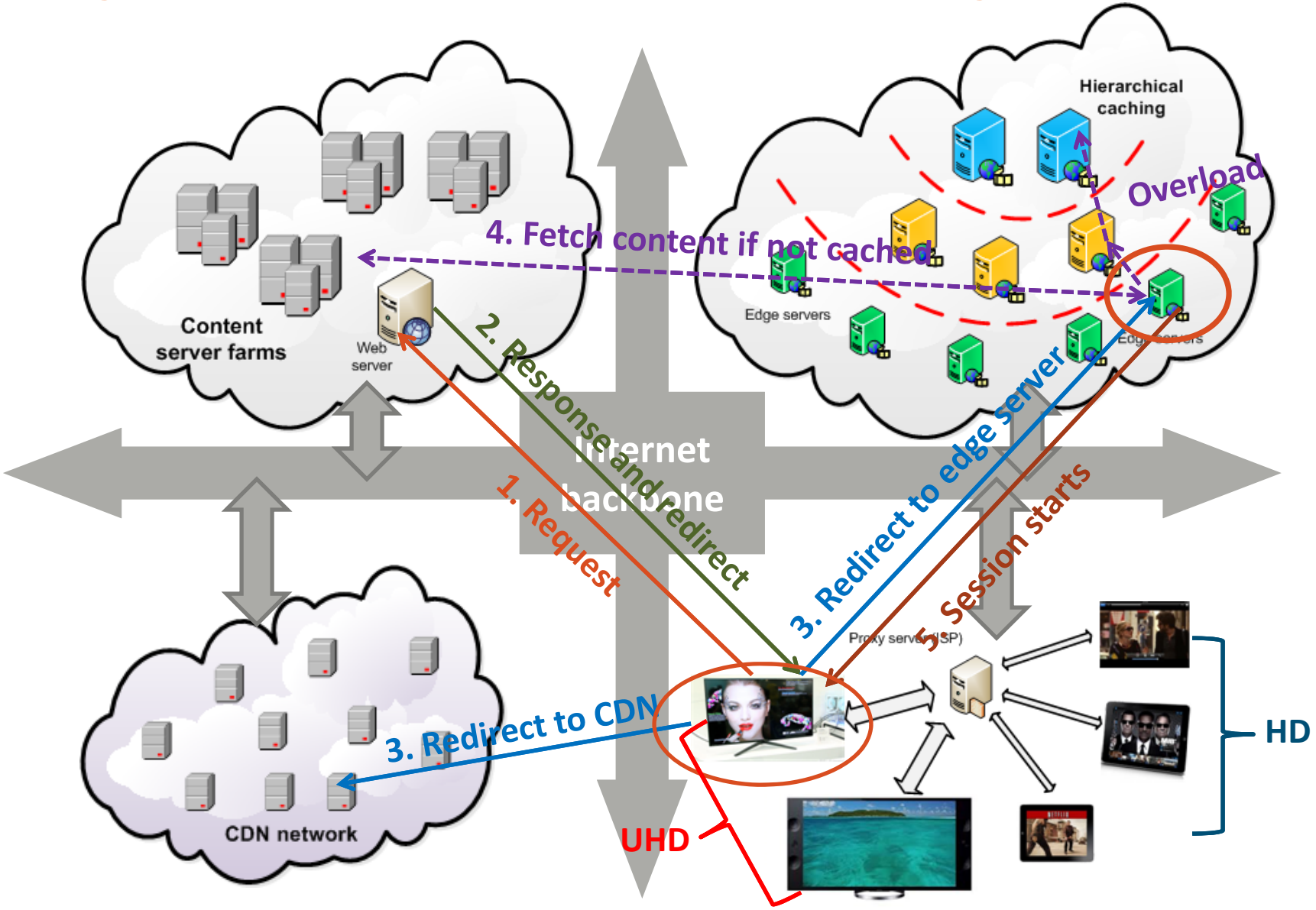
Large Scale Video Delivery System (e.g. YouTube)



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Storing UHD on edge servers

- Today, multiple coded copies of the same video are stored on edge servers

- With UHD, we will have even more versions of the same content taking up much more server space

UHD-1: 30Mbps x 2.5 hours ≈ 34GB
UHD-2: 75Mbps x 2.5 hours ≈ 84GB

Improved HEVC encoder

- Ultra High Definition (8kx4k)
- Ultra High Definition (4Kx2k)
- High Definition (1080p)
- High Definition (720p)
- High quality (480p)
- …

- Rather than storing independent versions (simulcast), scalable coding improves storage efficiency

UHD-1: 30Mbps x 2.5 hours x 70% ≈ 24GB → 10GB saving
UHD-2: 75Mbps x 2.5 hours x 70% ≈ 59GB → 25GB saving

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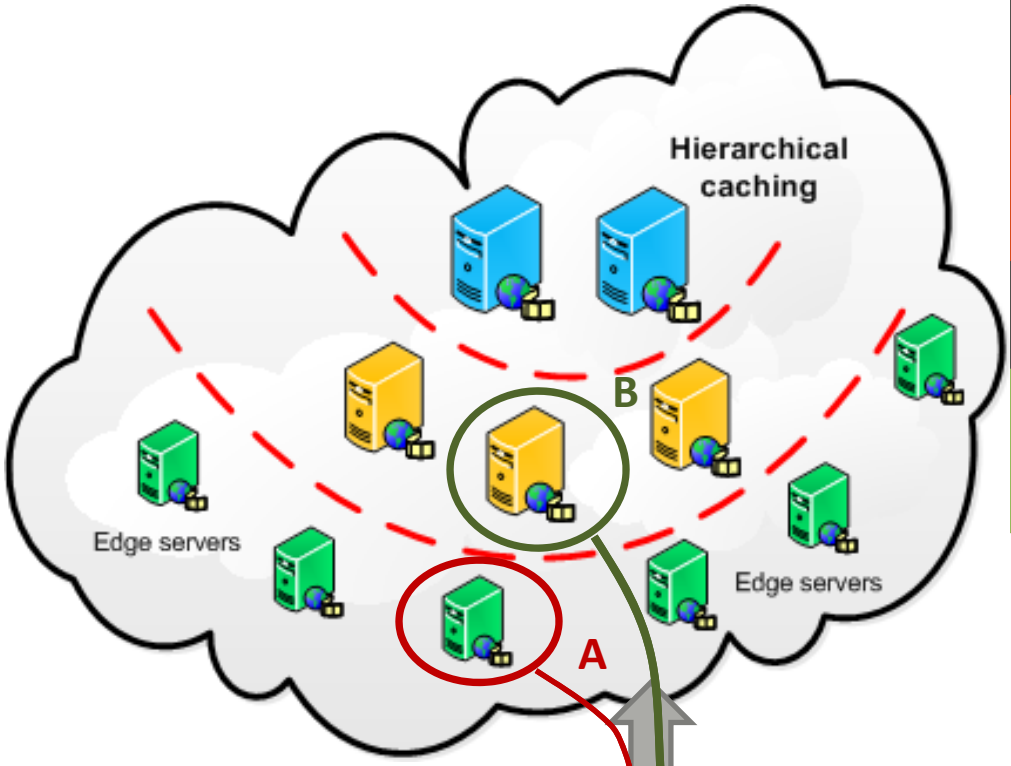
Streaming UHD with scalable codec

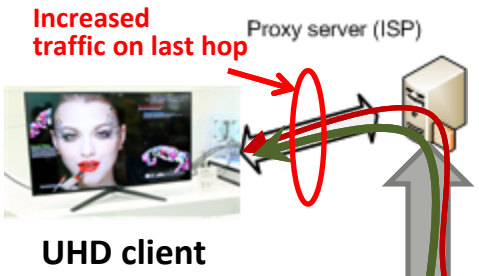
With scalable codec (e.g. SVC), HTTP streaming protocols (e.g. MPEG DASH) allow the client to receive base layer stream from server A and enhancement layer stream from

Problem: compared to single layer coding, scalable stream (BL + EL) increases bandwidth of the last hop

Server B: enhanced UHD service, farther away from UHD clients

Solution: Services such as Google fiber improve the last-hop bandwidth significantly





Internet backbone

EL video (UHD) stream

BL video (HD) stream

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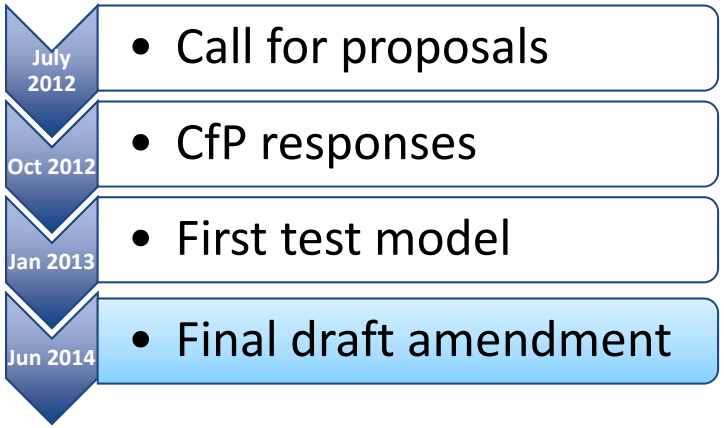
SHVC: scalable extensions of HEVC

- HEVC extensions currently under development:
  - JCT-VC is working on range extensions and scalable extensions (SHVC)
  - JCT-3V is working on various 3D extensions



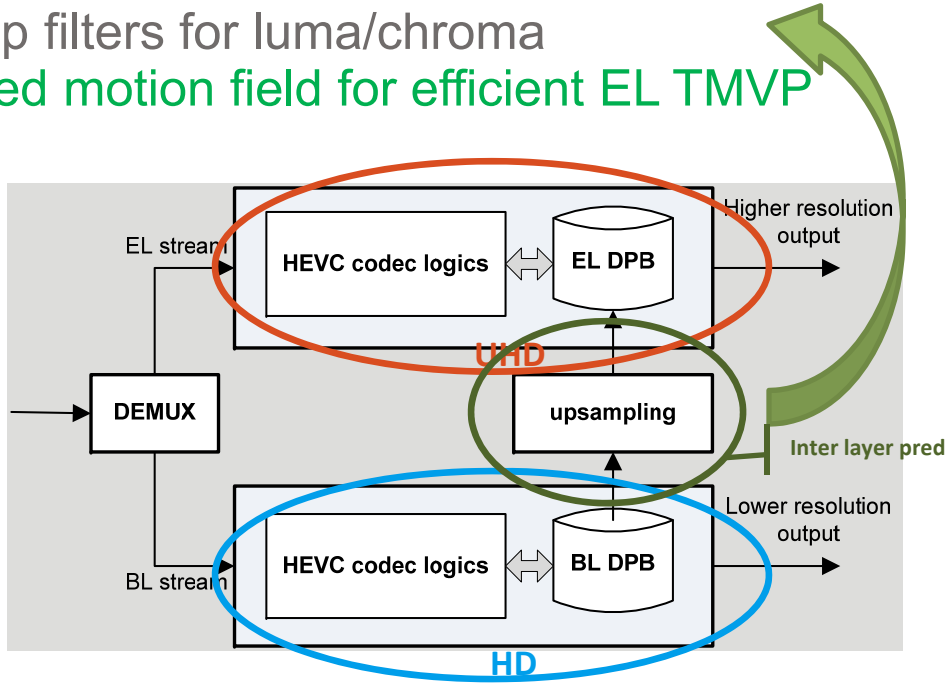
Feature	Standard			Examples	
	SVC	MVC	SHVC	Base layer	Enhance layer
Temporal	X		X (HEVC v1)	30fps	60fps
Spatial	X		X	720p	1080p
SNR	X		X	30dB	33dB
Standard			X	H.264/AVC	H.265/HEVC
View		X	JCT-3V	2D (1 view)	3D (≥2 views)
Bit-depth			AhG	8-bit	10/12-bit
Color gamut			AhG	BT.809	BT.2020
Chroma format			AhG	4:2:0	4:4:4/4:2:2

SHVC Features

- Inter-layer prediction is enabled through the “reference index” based concept
- Similar to multi-view solutions such as H.264/MVC and MV-HEVC
- Enhancement layer prediction = temporal references + inter layer references
- Multiple coding loops
- Upsampling applied to both reconstructed texture and motion field
  - Texture upsampling: 8-tap/4-tap filters for luma/chroma
  - Motion field mapping: resampled motion field for efficient EL TMVP

Design considerations

1. Minimal changes to block level logics of single layer codec
2. Reduced implementation cost
3. Unified design with multi-view
4. Hybrid codec support
5. Easy to extend to other scalabilities



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SHM1.0 Performance

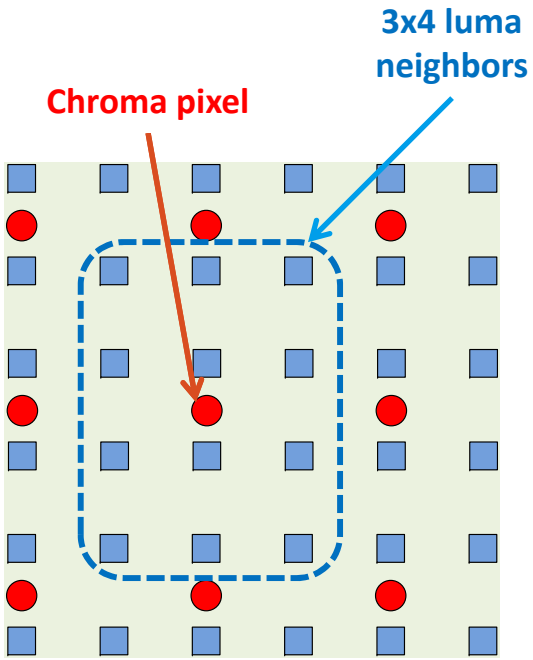
SHM1.0 performance on HD→UHD	
Rate reduction vs simulcast (BL + EL)	-18%
Rate reduction vs simulcast (EL only)	-30%
Rate increase vs single layer	22%

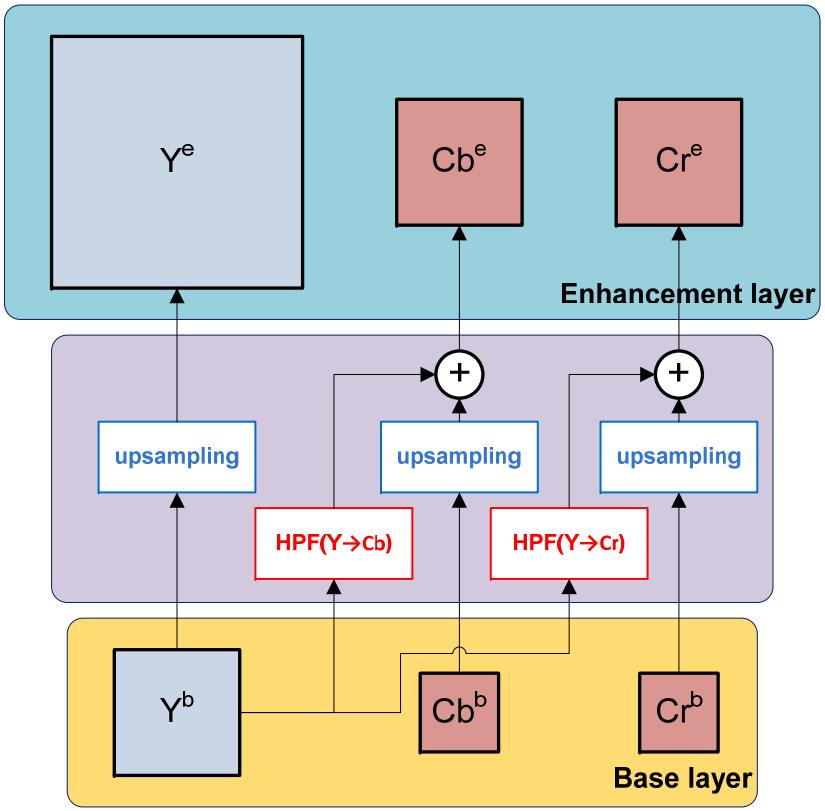
Notes:
- Scalable software: SHM1.0
- Single layer software: HM8.1
- Random Access config
- 2x scalability: HD → UHD
- QPB = {22, 26, 30, 34}
- QPE = QPB + { 0, 2}

- Fixed base layer coding
- Additional gain can be obtained with cross layer optimization
- Further coding efficiency gain can be achieved with other inter layer processing technologies
- Core Experiment on inter layer processing
  - Adaptive inter layer filters
  - Chroma enhancement filters
  - Inter layer SAO
  - Bi-lateral inter layer filters, etc
- Differential coding based inter layer reference enhancement

Chroma enhancement filters

- High pass filter on neighboring luma pixels to restore or enhance chroma signal quality
- As inter layer processing step, latency issue can be solved by operating directly on the base layer luma signal





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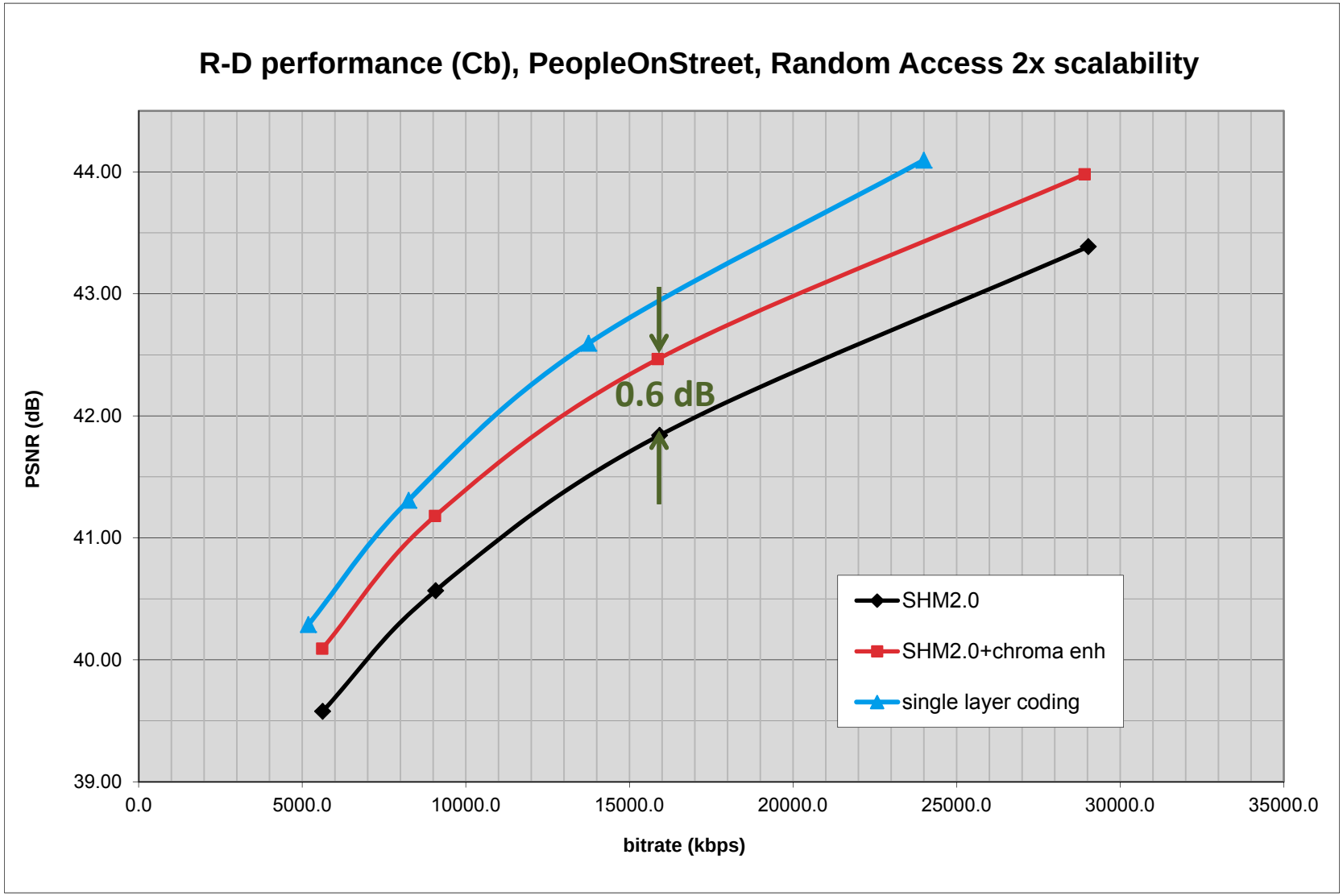
Chroma enhancement filter performance



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Handling UHD traffic with SHVC

- UHD and HD content will likely co-exist in the foreseeable future → scalable codec can provide benefits
- Improve storage efficiency on edge servers
- Improve transmission efficiency of the UHD content
- One of SHVC's main design considerations is to provide scalability with low implementation cost

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HEVC = best hybrid block-based video codec?

- How much more gain is achievable within the hybrid block based video coding framework?

Big winners in HEVC

- Large coding blocks
- Large transforms
- Quad-tree partition of blocks
- Sample Adaptive Offsets
- Advanced Motion Vector Prediction

Tool-by-tool performance: Entertainment Applications

	Up to 16x16 CTB	Up to 8x8 Transform	RQT depth =1	TMVP off	SAO off	AMP off
Class A	28.2%	12.2%	0.8%	2.6%	2.4%	0.6%
Class B	18.4%	9.3%	1.1%	2.2%	2.4%	0.7%
Class C	8.5%	4.2%	1.1%	2.4%	1.7%	1.1%
Class D	4.2%	2.4%	1.1%	2.7%	0.5%	0.9%
Average	**11.0%**	**5.4%**	**1.0%**	**2.5%**	**1.6%**	**0.9%**

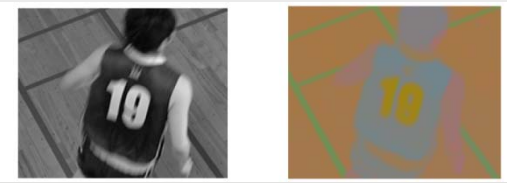
Block-based hybrid video coding framework

What did not work in HEVC

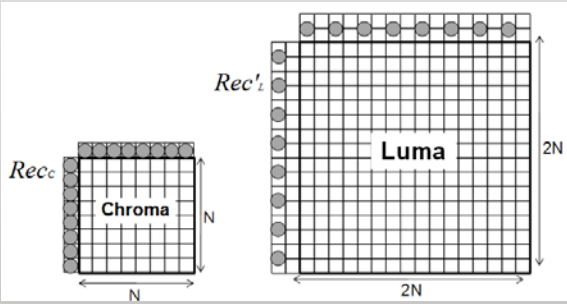
- Adaptive Loop Filters
- Linear Model (LM) chroma
- Short Distance Intra Prediction
- Decoder side motion derivation, …

Is HEVC the last block based codec?

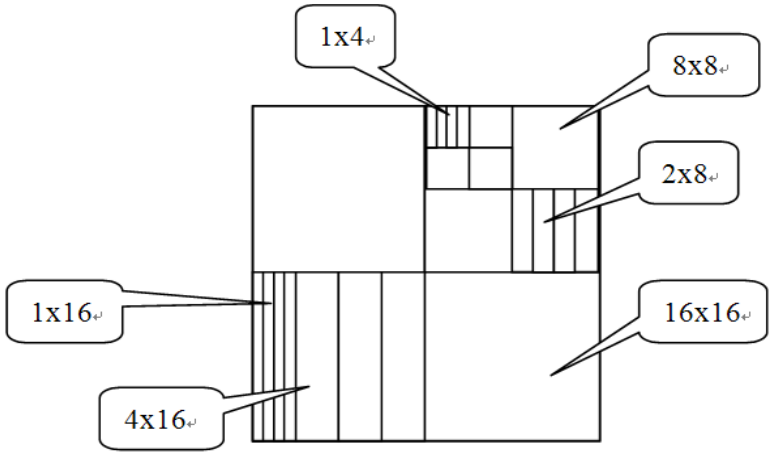
Unknown: the true bound of the rate-distortion curves



$$Pred_C[x,y] = \alpha \cdot Rec_L'[x,y] + \beta$$



LM chroma intra pred



SDIP

Non-square partitions and transforms:

32x32CU → 8x32/32x8

16x16CU → 4x16/16x4 → 1x16/16x1

8x8CU → 2x8/8x2, …

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Beyond block-based hybrid video coding

Beyond block-based codec

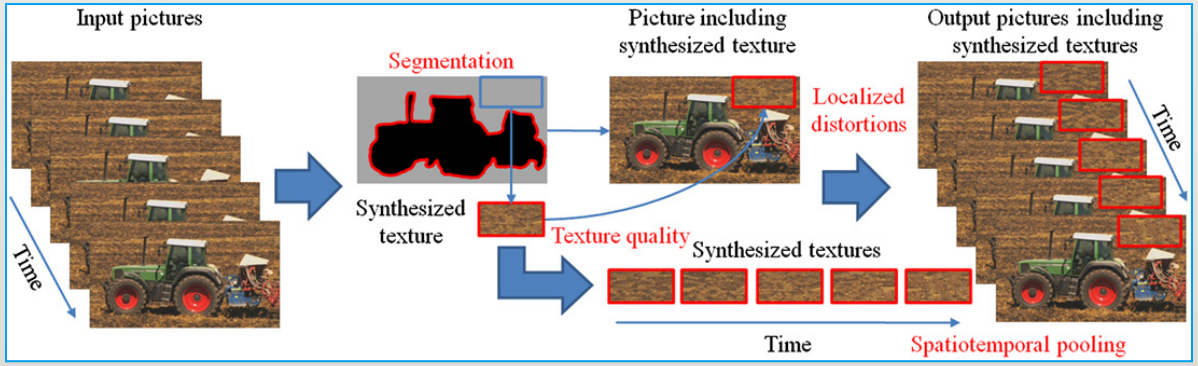
Texture analysis and synthesis based	Region-based	Object-based	Model-based	•••

Promise:

Captures perceptually important information without pixel based coding

Challenges:

Quality evaluation
Segmentation
Complexity increase



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Concluding thoughts

- UHD offers “look out the window” viewing experience

Broadband Unlimited conference, CES 2013, panel discussion on UHD TV

“When you have business at the production end and consumers showing big interest, the question is how do we distribute it to the home?”
-Larry Thorpe, senior fellow, professional engineering/solutions, Canon USA

- HEVC and its scalable extensions will facilitate UHD content distribution
- Improvements in network bandwidth will continue
- Other aspects of BT.2020 (e.g. wider color gamut) will continue to develop in the coming years

References

1. J. R. Ohm, G. J. Sullivan, H. Schwarz, T. K. Tan, T. Wiegand, **Comparison of the Coding Efficiency of Video Coding Standards –Including High Efficiency Video Coding (HEVC)**, *TCSVT special issue on HEVC, 2012.*
2. ISO/IEC JTC-1/SC29/WG11 w12957, **Joint Call for Proposals on Scalable Video Coding Extensions of High Efficiency Video Coding (HEVC)**, July 2012.
3. Nokia, **Updated test results of evaluation of H.265 / HEVC for 3GP-DASH,** *3GPP doc. no. S4-130708, July 2013.*
4. Qualcomm**, Additional test results for DASH**, 3GPP doc. no. *S4-130672, July 2013.*
5. P. Gill, M. Arlittz, Z. Li, A. Mahanti, **YouTube Traffic Characterization: A View From the Edge,** Proceedings of the 7th ACM SIGCOMM conference on Internet measurement, 2007
6. M. Zink, K. Suh, Y. Gu, J. Kurose, **Watch Global, Cache Local: YouTube Network Traffic at a Campus Network – Measurements and Implications,** ScholarWorks@UMass Amherst, 2008
7. K. Adhikari, S. Jain, Y. Chen, and Z-L Zhang, **Vivisecting YouTube: An Active Measurement Study,** Proceedings of IEEE INFOCOM, March 2012
8. **Common SHM test conditions and software reference configurations**, JCTVC doc. no. JCTVC-M1009, April 2013.
9. **SHVC working draft 2**, JCTVC doc. no. JCTVC-M1008, April 2013.
10. **HEVC scalable extensions Core Experiment 3 (SCE3): inter layer filtering**, JCTVC doc. no. JCTVC-M1103, April 2013.
11. InterDigital, **Chroma enhancement for ILR picture**, JCTVC doc. no. JCTVC-L0059, January 2013
12. Samsung, **Simplified design of cross-color inter layer filter,** JCTVC doc. no. JCTVC-M0089, April 2013.
13. Nokia, **Enhanced inter layer reference picture for RefIdx based scalability**, JCTVC doc. no. JCTVC-M0155, April 2013.
14. InterDigital, **ILR enhancement with differential coding for RefIdx framework**, JCTVC doc. no. JCTVC-M0189, April 2013.
15. P. Ndjiki-Nya, D. Doshkov, H. Kaprykowsky, F. Zhang, D. Bull, and T. Wiegand: **Perception-oriented video coding based on image analysis and completion: A review**, *Signal Processing: Image Communication*, vol. 27, no. 6, pp. 579-594, February 2012.
16. G. J. Sullivan, J. R. Ohm, A. Ortega, E. Delp, A. Vetro, M. Barni, **dsp Forum – Future of Video Coding and Transmission**, IEEE Signal Processing Magazine 23 (6) 2006.

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THANK YOU

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