MANIPULATING UHD VIDEO TRAFFIC

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InterDigital Communications
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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

10 preloaded features and short video

FMX-XP 4K media player and hub ($699)
UHD product announcements

DISPLAYS
- SAMSUNG
- LG
- TOSHIBA
- SEIKI
- SONY
- ViewSonic
- SHARP

BROADCASTERS
- BBC
- Comcast
- ESPN
- NHK

REAL TIME 4K ENCODER/DECODERS
- harmonic
- QUALCOMM
- ateME
- BROADCOM

INDUSTRY CONSORTIUM
- ATSC
- HDMI
- Blu-ray Disc

CAMERAS
- RED
- ASTRO
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

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

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

UHD TV

Display

Decoding

Streaming box

HDMI cable
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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

<table>
<thead>
<tr>
<th>Sequences</th>
<th>Bit rate savings at same MOS (HEVC vs. H.264/AVC HP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1080p</td>
<td></td>
</tr>
<tr>
<td>BQTerrace</td>
<td>63.1%</td>
</tr>
<tr>
<td>BasketballDrive</td>
<td>66.6%</td>
</tr>
<tr>
<td>Kimono</td>
<td>55.2%</td>
</tr>
<tr>
<td>ParkScene</td>
<td>49.7%</td>
</tr>
<tr>
<td>Cactus</td>
<td>50.2%</td>
</tr>
<tr>
<td>Average</td>
<td>57%</td>
</tr>
</tbody>
</table>

| WVGA (720x480)  |                                                      |
| BQMall          | 41.6%                                                |
| BasketballDrill | 44.9%                                                |
| PartyScene      | 29.8%                                                |
| RaceHorses      | 42.7%                                                |
| Average         | 40%                                                  |

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\}
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

<table>
<thead>
<tr>
<th>Resolution</th>
<th>S4-130672</th>
<th>S4-130708</th>
</tr>
</thead>
<tbody>
<tr>
<td>1080p</td>
<td>42.2%</td>
<td>40.4%</td>
</tr>
<tr>
<td>720p</td>
<td>34.9%</td>
<td>35.8%</td>
</tr>
<tr>
<td>480p</td>
<td>31.9%</td>
<td>34.1%</td>
</tr>
<tr>
<td>240p</td>
<td>27.1%</td>
<td>30.9%</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>33.3%</strong></td>
<td><strong>35.3%</strong></td>
</tr>
</tbody>
</table>

**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

Although UHD has more pixels, the bit cost per pixel is lower
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
Large Scale Video Delivery System (e.g. YouTube)
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

- 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
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 server B.

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.

Increased traffic on last hop.

Proxy server (ISP).

UHD client.
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

<table>
<thead>
<tr>
<th>Feature</th>
<th>Standard</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SVC</td>
<td>MVC</td>
</tr>
<tr>
<td>Temporal</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Spatial</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>SNR</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Standard</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>View</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Bit-depth</td>
<td></td>
<td>AhG</td>
</tr>
<tr>
<td>Color gamut</td>
<td></td>
<td>AhG</td>
</tr>
<tr>
<td>Chroma format</td>
<td></td>
<td>AhG</td>
</tr>
</tbody>
</table>
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
SHM1.0 Performance

<table>
<thead>
<tr>
<th>SHM1.0 performance on HD→UHD</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate reduction vs simulcast</td>
<td>-18%</td>
</tr>
<tr>
<td>(BL + EL)</td>
<td></td>
</tr>
<tr>
<td>Rate reduction vs simulcast</td>
<td>-30%</td>
</tr>
<tr>
<td>(EL only)</td>
<td></td>
</tr>
<tr>
<td>Rate increase vs single layer</td>
<td>22%</td>
</tr>
</tbody>
</table>

**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
Chroma enhancement filter performance

R-D performance (Cb), PeopleOnStreet, Random Access 2x scalability

- SHM2.0
- SHM2.0+chroma enh
- single layer coding

PSNR (dB) vs. bitrate (kbps) graph showing a 0.6 dB improvement.
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

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

\[ \text{Pred}_C[x,y] = \alpha \cdot \text{Rec}_L[x,y] + \beta \]

LM chroma intra pred

**SDIP**
Non-square partitions and transforms:
- 32x32CU → 8x32/32x8
- 16x16CU → 4x16/16x4 → 1x16/16x1
- 8x8CU → 2x8/8x2, ...
Beyond block-based hybrid video coding

**Promise:**
Captures perceptually important information without pixel based coding

**Challenges:**
- Quality evaluation
- Segmentation
- Complexity increase
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

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
THANK YOU

Q & A