High Efficiency Video Coding: The Next Gen Codec

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High Efficiency Video Coding
Compression Bitrate Targets

- MPEG-2 VIDEO
  - 1994
  - 50% bitrate saving target

- AVC
  - 2003
  - 50% bitrate saving target

- HEVC
  - 2013
HEVC

• A new standardized compression algorithm
  – An evolution of AVC (H.264 | MPEG-4 Part 10)

• HEVC standardization
  – A Joint Collaborative Team on Video Coding (JCT-VC) of MPEG & VCEG
  – Aim: To deliver same picture quality for half the bitrate of AVC
    • Up to 10x more computational complexity to encode and 2x-3x to decode

• Key dates
    Main Profile, Main 10 Profile, and Main Still Profile approved
    • VCEG consented; Final text available March 1 → MPEG to issue ballot for ratification
  – January 2014 FDAM – Range extensions (Contribution applications) & Multi-view extensions
  – July 2014 FDIS – Scalable HEVC (SHVC)
HEVC Encoder

ENCODER CONTROL

Ref. Buffer
Intra
ME/MC
Mode Dec
Recon
Prediction
Residuals

Headers

ALF
SAO
DF

T^-1
Q^-1
T
Q

Bitstream

Source

Entropy Coder

Headers

Bitstream

Source

Entropy Coder
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, 4x4 transform sizes
Coding Tree

- Coding Tree is a collection of Coding Units (CU) – CUs can have independent coding modes.
- Further partitioning using Prediction Units (Motion Vectors).
- Independent Transform Tree partitioning from 32x32 to 4x4.
CUs: Prediction & Transform Units

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

Source: JCTVC-A124
HEVC Tools – Intra Prediction

**AVC**
- DC +
- 8 directional modes

**HEVC**
- DC + Planar +
- 33 directional modes

% of bits

<table>
<thead>
<tr>
<th></th>
<th>MPEG2</th>
<th>AVC</th>
<th>HEVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of bits</td>
<td>250</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>Media Type</td>
<td>MPEG2</td>
<td>AVC</td>
<td>HEVC</td>
</tr>
</tbody>
</table>
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
## Tool Comparison: AVC HP vs. HEVC MP

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

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

- For DTH, HEVC will give 40-50% saving over best AVC encoder today
  - HD: AVC 6 - 9 Mbps → HEVC 3 - 4.5 Mbps
  - SD: AVC 1.5 - 2.5 Mbps → HEVC 0.8 - 1.5 Mbps
  - UHD 4K: AVC 16 - 24 Mbps (estimate) → HEVC 8 - 12 Mbps
    - Fits in existing channel bandwidth of currently deployed HD!

- HEVC practical availability
  - Driven by availability of receive devices
  - Software-based implementations available now; address a subset of applications
  - First production silicon available during 2013 → first practical systemization 1H14
  - Implementation issues (impacts practical ability to deploy)
    - Migration of deployed (legacy) vs. greenfield
    - Intellectual property licensing needs to be settled → MPEG LA
    - UHDTV (4K) uncertainty: Main 10 Profile? Higher frame rate?
    - Better interlaced content support?
  - Contribution market – Professional profiles (“RExt”, e.g., 4:2:2) planned Jan. 2014
Industry Drivers - Efficiency

Mobile TV
- Expensive bandwidth
- Increasing demand

Multi-screen
- More HD
- More screens

xDSL reach
- More subscribers

DSNG
- More HD
- Expensive bandwidth

Satellite Distribution
- Spectrum efficiency

UHDTV
- High bit-rate need

Terrestrial Broadcast
- Spectrum efficiency

Expensive bandwidth
Increasing demand
More HD
More screens
More subscribers
More HD
Expensive bandwidth
Spectrum efficiency
High bit-rate need
HEVC Version 1 Contains 3 Profiles

• Main Profile supports general consumer-grade video (4:2:0 8-bit)

• Main 10 Profile targets large screen consumer applications that require higher resolution
  – Main Profile + bit-depth up to 10 bits
  – UHDTV and large screens
  – Not for professional applications (contribution, mastering)

• Still Picture Profile targets specialty applications
  – Strict sub-set of Main Profile
  – One IDR picture

• Some practical concerns still remain …
Interlaced Tools Disagreements

• De-interlace prior to encoding
  – Shown to give great efficiency results
  – Doesn’t fit all usage scenarios
    • DTA, embedded transcoding
    • Billions of pre-encoded MPEG-2 Video & AVC source content

• PAFF/MBAFF (AVC) vs. SAFF/Field Only Coding/Frame Only Coding (HEVC)
  – What about PAFF without MBAFF?

• Chroma bleeding in 4:2:0 (no chroma motion vector offset when predicting top-to-bottom / bottom-to-top field as AVC)

• WG11 has asked for more evidence before proceeding further
Resolution revolution
What is UHDTV(4K)?

• 4x spatial resolution of HDTV
  – 3840 x 2160 YCrCb (4:2:2 10bit)
UHDTVs Now Available
Visual Perception - Resolution

0.01°

1.3x to 2.6x diagonal

9' to 18' for 84” diagonal

84” TV
UHDTV – Key Consumer Value

High-quality movies

Popular sports events
UHDTV Short Term Challenges

- HDMI 1.4 does not support 4Kp60
- 4 x 3G-SDI
- Production mixers
- Graphics
- Live cameras
- Set-top boxes for DTH
On What Format Will Industry Settle For 4K UHDTV?

4K HEVC could require up to 80x more horsepower vs. HD AVC

| Format   | Resolution   | Bits | Color | Frame Rate | Bandwidth
|----------|--------------|------|-------|------------|-----------
| SDTV     |              |      |       |            |           
| HDTV     |              |      |       |            |           
| 4KTV P30 | 8b 4:2:0     |      |       |            |           
| 4KTV P60+| 10b 4:2:2    |      |       |            |           
| Film OCN |              |      |       |            |           

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Driving UHDTV Content & Events

Movies

Live sports

TV dramas

2014

FIFA WORLD CUP Brasil

Rio 2016
Contribution: 4:2:2 vs. 4:2:0

Chroma rate = ¼ Luma rate
Saves 50% bandwidth

Chroma rate = ½ Luma rate
Saves 33% bandwidth

10-Bit Quantization

8 bit = 0 to 255
10 bit = 0 to 1023
HEVC Range Extensions

• HEVC range extensions (RExt) will be an Annex to HEVC v1
  – 4:2:2/4:4:4/RGB chroma formats
  – Higher bit-depths, including 10/12/14
  – Mixed Chroma formats (4:2:0 & 4:4:4) – mixed video (4:2:0) and computer graphics (4:4:4)
  – Lossless Coding

• As of January 2013 meeting cycle
  › Use square transform and square intra prediction
  › Intra prediction angle adjustment for 4:2:2
  › Software to support both square and non-square transforms

• Timeline
  – DAM July 2013
  – FDAM January 2014
  – But, schedule may slip out due to efficiency concerns …
### Comparison of AVC-I and HEVC-I vs. SSStP

<table>
<thead>
<tr>
<th>Sequence name</th>
<th>Target Y/G SNR</th>
<th>BD-Rates of AVC vs SSStP</th>
<th>BD-Rates of HEVC vs SSStP</th>
<th>BD-Rates of HEVC vs AVC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Y/G</td>
<td>Cb/B</td>
<td>Cr/R</td>
<td>Y/G</td>
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<tr>
<td>Kimono</td>
<td>56.72</td>
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<td>EBUUboCandlelight</td>
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<td>VenueVu</td>
<td>63.78</td>
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<td>DucksAndLegs</td>
<td>60.93</td>
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<tr>
<td>OldTownCross</td>
<td>52.48</td>
<td>-12.84</td>
<td>-12.94</td>
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<tr>
<td>Average sequence</td>
<td>56.71</td>
<td>-10.68</td>
<td>-11.31</td>
<td>-10.65</td>
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<tr>
<td>YCbCr 4:2:2</td>
<td>QP &lt; 1 required</td>
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<td>Kimono</td>
<td>54.86</td>
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<td>EBUWaterRocksClose</td>
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<td>EBUKidsSoccer</td>
<td>48.78</td>
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<tr>
<td>Average sequence</td>
<td>50.73</td>
<td>-17.87</td>
<td>-13.92</td>
<td>-13.44</td>
</tr>
</tbody>
</table>

Only 5% improvement over AVC!
Possible Profiles and Conflicting Goals

- Possible profiles
  - Consumer – lower bitrates, few changes over v1
  - Professional – high bitrates, new tools for performance gains, divergence from v1

- Mixed content – more applicable to consumer applications (e.g., gaming) but requires new tools (divergence from v1)

- Is consumer profile a subset of Professional or can there be a divergence at a tool level (i.e., mutually exclusive transform designs)?
4K UHD Contribution using AVC

4K source → 4x 3G-SDI

- 4x AVC encoders synchronized

or

- 4x AVC decoders
  - phase-lock synchronization

fiber

UHD/4K display
Scaleable HEVC (SHVC)

Annex F

Add new reference pictures for Scaleable and Multi-view Extensions

Annex G

Motion compensation on up-sampled decoded base layer pictures

Annex H

New CU level coding tool for Inter layer prediction