Questions

● For more information, check out the book
  ● “A beacon of light in a valley of half-knowledge”
    ● Mustafa Isik, on Twitter
Agenda

- What is HEVC?
- Royalty status
- How quality compares to H.264
- Encoding/decoding status
- Market status
  - OTT
  - Streaming
- Where I messed up
  - MPEG-LA
  - Maybe Frost and Sullivan
What is HEVC

- Successor to H.264
  - January 2013 – “first stage approval”
  - Essentially cleared for sale
- Key benefits
  - Same quality as H.264 at 35-50% data rate:
    - Reduce bandwidth costs
    - Send HD through smaller pipes
    - Send more videos through existing pipes
  - Enable Ultra HD videos (UHD)
  - (technical links at the end of the article)
Technical Comparison

- From Elemental White paper
- MPEG-2/H.264/HEVC

<table>
<thead>
<tr>
<th>COMPONENT</th>
<th>MPEG-2</th>
<th>H.264</th>
<th>HEVC/H.265</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Motion compensated predictive, residual, transformed, entropy coded</td>
<td>Same basics as MPEG-2</td>
<td>Same basics as MPEG-2</td>
</tr>
<tr>
<td>Intra prediction</td>
<td>DC Only</td>
<td>Multi-direction, multi-pattern, 9 intra modes for 4x4, 9 for 8x8, 4 for 16x16</td>
<td>35 modes for intra prediction, 32x32, 16x16, 8x8 and 4x4 prediction size</td>
</tr>
<tr>
<td>Coded Image Types</td>
<td>I, B, P</td>
<td>I, B, P, SI, SP</td>
<td>I, P, B</td>
</tr>
<tr>
<td>Transform</td>
<td>8x8 DCT</td>
<td>8x8 and 4x4 DCT-like Integer Transform</td>
<td>32x32, 16x16, 8x8 and 4x4 DCT-like Integer Transform</td>
</tr>
<tr>
<td>Motion Estimation Blocks</td>
<td>16x16</td>
<td>16x16, 16x8, 8x16, 8x8, 8x4, 4x8, 4x4</td>
<td>64x64 and hierarchical quad-tree partitioning down to 32x32, 16x16, 8x8</td>
</tr>
<tr>
<td>Entropy Coding</td>
<td>Multiple VLC tables</td>
<td>Context adaptive binary arithmetic coding ( CABAC ) and context adaptive VLC tables ( CAVLC )</td>
<td>Context adaptive binary arithmetic coding ( CABAC )</td>
</tr>
<tr>
<td>Frame Distance for Prediction</td>
<td>1 past and 1 future reference frame</td>
<td>Up to 15 past and/or future reference frames, including long-term references</td>
<td>Up to 15 past and/or future reference frames, including long-term references</td>
</tr>
<tr>
<td>Fractional Motion Estimation</td>
<td>½ pixel bilinear interpolation</td>
<td>½ pixel 6-tap filter, ¼ pixel linear interpolation</td>
<td>½ pixel 8-tap filter</td>
</tr>
<tr>
<td>In-Loop Filter</td>
<td>None</td>
<td>Adaptive deblocking filter</td>
<td>Adaptive deblocking filter and sample adaptive offset filter</td>
</tr>
</tbody>
</table>

bit.ly/Elemental_HEVCWP

Streaming Learning Center
Royalty Status

- What’s known: MPEG LA patent group
  - $0.20/encoder/decoder
  - Shipments in excess of 100,000
  - $25 million annual maximum (first year only)
  - No HEVC content royalty (even PPV/subscription)

- What’s unknown
  - Many very prominent IP owners, including Microsoft, Panasonic, Dolby and Samsung
    - bit.ly/HEVC_whosout
Impact of HEVC Royalty

- **Encoder**
  - Very few companies will meet 100,000 minimum
  - Those that do will usually hit maximum and are really big companies
    - Apple, Google, Microsoft

- **Hardware decoder (broadcast, OTT)**
  - Can offset $0.20/unit cost

- **Software decoder (Flash, browser vendors)**
  - Lots of news here; will cover later
Quality Comparisons

- Expectation: Same quality as H.264 @ 50% data rate
- My tests
  - 3 files, animation (sintel), movie trailer (TOS), real world video
  - Two HEVC configurations
    - 720p @ 2 mbps
    - 1080p @ 4 mbps
  - Two H.264 configurations
    - 720p @ 4 mbps (200%) and 3 mbps (150%)
    - 1080p @ 8 mbps (200%) and 6 mbps (150%)
- Assess quality with Moscow University VQMT
Quality Comparisons

- Results: Video Quality Metric (like PSNR, SSIM, but better)
  - Lower scores better

<table>
<thead>
<tr>
<th></th>
<th>HEVC/VP9 Data Rate</th>
<th>VP9</th>
<th>Best HEVC</th>
<th>Miss %</th>
<th>H.264 @ 2X Data Rate</th>
<th>H.264 @ 1.5X Data Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>New 1280</td>
<td>2,000</td>
<td>0.543</td>
<td>0.624</td>
<td>7.15%</td>
<td>0.579</td>
<td>0.628</td>
</tr>
<tr>
<td>New 1920</td>
<td>4,000</td>
<td>0.510</td>
<td>0.573</td>
<td>0.44%</td>
<td>0.570</td>
<td>0.610</td>
</tr>
<tr>
<td>Sintel 1280</td>
<td>1,300</td>
<td>0.785</td>
<td>0.852</td>
<td>26.79%</td>
<td>0.624</td>
<td>0.724</td>
</tr>
<tr>
<td>Sintel 1920</td>
<td>2,500</td>
<td>0.760</td>
<td>0.791</td>
<td>13.61%</td>
<td>0.683</td>
<td>0.763</td>
</tr>
<tr>
<td>Tears 1280</td>
<td>1,300</td>
<td>0.910</td>
<td>0.914</td>
<td>4.71%</td>
<td>0.871</td>
<td>0.973</td>
</tr>
<tr>
<td>Tears 1920</td>
<td>2,500</td>
<td>0.788</td>
<td>0.804</td>
<td>-1.42%</td>
<td>0.816</td>
<td>0.896</td>
</tr>
</tbody>
</table>

Same quality at 50% data rate | Same quality at 66% data rate
Conclusions

- Very close to 50% claim in real world videos/movies
  - Every test case delivered at least same quality or better at 66% file size
- Animation was substantially behind
  - X264 has animation tuning; X265 doesn’t (yet), or at least the version I used didn’t
  - Not sure if this is idiosyncratic to video, but if your content is animation, test early to gauge your results
Where Will It Play

- Limited sample
  - 720p HEVC should play on most 2-core computers
  - 1080p will only play on 4/8 core and above
  - (I’m guessing that) by far, the bulk of video streamed today is 720p or smaller (at least non-OTT)

<table>
<thead>
<tr>
<th></th>
<th>H264 720p</th>
<th>HEVC 720p</th>
<th>H264 1080p</th>
<th>HEVC 1080p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dell Precision 390</td>
<td>24%</td>
<td>40%</td>
<td>30%</td>
<td>Fail</td>
</tr>
<tr>
<td>2.93 GHz Core 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mac 3.06 GHz Core 2 Duo</td>
<td>18%</td>
<td>39%</td>
<td>35%</td>
<td>Fail</td>
</tr>
<tr>
<td>HP Elitebook 8760</td>
<td>10%</td>
<td>18%</td>
<td>20%</td>
<td>21%</td>
</tr>
<tr>
<td>i7-2820 (4/8 core)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Decoding HEVC (mobile and devices)

- Horsepower exists
  - New iPad and many other tablets s/be HEVC capable via software only
  - Multiple chips like Qualcomm Snapdragon 800 with some **HEVC hardware decode** now shipping
  - More coming
- Lots of non-pc units coming in many categories
- Battery life key in mobile

*Source: Frost & Sullivan*
Caveat: Battery Life

- Techspot: Mobile Playback tests
  - H.264@1080p -- 8.6 hours
  - HEVC@1080p – 4.36 hours
  - While HEVC delivers fantastic quality for the file size, it’s impractical for a battery-powered device when it lasts half as long as an equivalent-resolution H.264 file.
  - bit.ly/HEVC_batt
Bottom Line on Playback

- Streaming to computers
  - Opportunity for bandwidth savings for 720p
  - 1080p CPU playback requirements may exclude too many older computers

- Streaming to mobile
  - Only the most recent generations in software
    - Battery life may limit HEVC’s desirability among users
    - Not aware of any testing done with Android decoder
  - Hardware support coming very soon (may be here already)

- OTT – of course, will play on STB
What About Infrastructure

- Encode
- Decode
Encoding HEVC

- Many vendors have announced and are either shipping or close to shipping
  - Elemental, Ateme, NEC - Live 4Kp60 10-bit
  - Others have live coming
  - Virtually all on-demand encoders working on HEVC
Encoding HEVC

What will the configuration options look like?

- Vary by vendor and product
  - But, lots in common with existing encoding tools
    - Profile, bitrate control (VBR/CRB/CRF), GOP (I, B, P), Key frame interval, B-frame interval, reference frame, etc.

- MainConcept
- Elemental
- Harmonic
HEVC Configuration Options - MainConcept

- Will vary by vendor
- MainConcept – access to profile, level, etc, plus:
  - Coding tree unit configuration
  - Sample adaptive offset
  - Wavefront Parallel Processing
  - Use case documentation to come with final product
HEVC Configuration Options - Squeeze

- Squeeze
- Lots of options/5 presets
- No real direction regarding how/when to use
- Will post user feedback when received
HEVC Configuration Bottom Line

- Many similar concepts, VBR, CBR, frame types, GOP, profiles, levels, search, etc.

- Depending upon vendor and/or product, you may have to learn 2-3 new configuration options (or trust defaults)

- These new options may provide meaningful tuning options if well documented/you can experiment
## H.265 Experimentation

<table>
<thead>
<tr>
<th>Feature</th>
<th>VQM</th>
<th>Difference from Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.68606</td>
<td></td>
</tr>
<tr>
<td>Tune – PSNR</td>
<td>0.68174</td>
<td>0.63%</td>
</tr>
<tr>
<td>Tune – SSSIM</td>
<td>0.68308</td>
<td>0.43%</td>
</tr>
<tr>
<td>Preset – Very slow</td>
<td>0.63896</td>
<td>6.87%</td>
</tr>
<tr>
<td>Increase data rate by 25%</td>
<td>0.64075</td>
<td>6.60%</td>
</tr>
</tbody>
</table>

### Conclusion:
- Some experimentation beneficial to identify optimal encoding configuration
HEVC vs. VP9 (How I spent the Weekend Before SMW)

- Most authorities assume that HEVC will produce better quality than VP9 at similar data rates
- My tests this weekend seem to refute this
- But, some potential issues
  - Google encoded all VP9 files (but supplied CLI parameters so I could duplicate)
  - IC HEVC vendor encoded theirs
  - I produced set from encoder that used x265 codec (presets not reviewed by encoding vendor)
  - I converted files to YUV for testing with MSU VQMT
HEVC vs. VP9

- FFMPEG inserted an extra frame in some files, which necessitated additional processing step
- Not 100% certain this didn’t skew results, and didn’t have time for subjective comparison between the files
- But:
  - VP9 files, on files that were and were not post-processed, had consistently higher quality than HEVC
  - HEVC files, both with and without post-processing, were consistently of lower quality, at or around the same ratio
More Caveats

- Encoding time not considered
  - Used medium preset (default) for x265 (not sure what Google used)
    - Google encoded at their facilities, didn’t report times (and I haven’t looked at their command line arguments)
- Avni Rambhia (Frost and Sullivan analyst) says I should expand test to other HEVC codecs
- Haven’t looked at VP9 playback side at all
- Will re-run tests on same platform and report encoding times, find workaround to frame issue, add other HEVC codecs and report in future Streaming Media article
## My Results

<table>
<thead>
<tr>
<th>HEVC IP Provider</th>
<th>x265</th>
<th>Lowest HEVC</th>
<th>VP9</th>
<th>Comp</th>
</tr>
</thead>
<tbody>
<tr>
<td>New 1280</td>
<td>0.624</td>
<td>0.624</td>
<td>0.543</td>
<td>-12.96%</td>
</tr>
<tr>
<td>New 1920</td>
<td>0.573</td>
<td>0.573</td>
<td>0.510</td>
<td>-10.97%</td>
</tr>
<tr>
<td>New 4K</td>
<td>0.481</td>
<td>0.481</td>
<td>0.454</td>
<td>-5.47%</td>
</tr>
<tr>
<td>Sintel 1280</td>
<td>0.852</td>
<td>0.852</td>
<td>0.785</td>
<td>-7.86%</td>
</tr>
<tr>
<td>Sintel 1920</td>
<td>0.791</td>
<td>0.791</td>
<td>0.760</td>
<td>-3.89%</td>
</tr>
<tr>
<td>Sintel 4K</td>
<td>0.549</td>
<td>0.549</td>
<td>0.534</td>
<td>-2.73%</td>
</tr>
<tr>
<td>Tears 1280</td>
<td>0.914</td>
<td>0.914</td>
<td>0.910</td>
<td>-0.48%</td>
</tr>
<tr>
<td>Tears 1920</td>
<td>0.804</td>
<td>0.804</td>
<td>0.788</td>
<td>-2.01%</td>
</tr>
<tr>
<td>Tears 4K</td>
<td>NA</td>
<td>0.675</td>
<td>0.750</td>
<td>11.18%</td>
</tr>
</tbody>
</table>
More Caveats

● My expectation?
  ● VP8 was at least as good as H.264
  ● I expect VP9 to be very competitive. If not better, than certainly in the ballpark

● The question is, does it matter?
  ● Answer, do Firefox and Opera matter?
    ● Hold that thought
HEVC Software Players

- DivX 10 with HEVC decode shipped – 9/2013
  - Installed base over 10 million
- VLC Player with HEVC – 11/15/2013
- Flash – Adobe to include HEVC decode in Primetime platform in 2015 but not Flash Player
  - Likely never a free, pervasively distributed software plug-in
  - So, it’s up to the browser vendors via Media Source Extensions and DASH
What About the Browsers?

- Apple:
  - Added HEVC encode/decoder for FaceTime only in iPhone 6 (http://bit.ly/iphone_HEVC)
  - Is paying royalty on those devices. No reason not to use in camera, include decode in Safari/iOS
  - Will likely reach maximum on iPhone/iPads – free everywhere else (not that $25 mil is big deal to Apple)
  - Best guess: In Safari by mid 2015
    - How far back will they go? What OS requirements?
    - Not so important b/c most users upgrade to latest OS
What About the Browsers?

- Google:
  - Google only pay royalties on products they sell (Android OEMs pay for their sales, not Google). Not sure Google reaches maximum
    - Ditto on $25 million –more strategic decision if and when
    - Pushing VP9, though never did remove H.264 from Chrome (smart move)
  - Best guess – yes, mid 2015
What About the Browsers?

- Microsoft:
    - Media Source Extensions only extend back to Windows 8.1
    - Unlike Apple, extending backwards is a big deal, because most MS users have not updated to latest OS

- Firefox/Opera: ROTFL
  - Will support MSE/VP9 – but feels like direct HEVC support is unlikely
HTML5 Then

- Firefox/Opera never licensed H.264
  - Firefox could playback vis OS support, both via Flash fallback
HTML5 Now

- Firefox/Opera will never license HEVC
  - No OS or Flash support to fall back to
  - Likely that to support Firefox/Opera, will have to use VP9

Streaming Learning Center
Browser Share Today

- VP9 capable – 60%
- HEVC capable – 0%

http://www.w3counter.com/globalstats.php
Explain to me why VP9 isn’t important

- I’m waiting
Conclusions

- It’s a freaking mess
- H.264 isn’t going anywhere; neither is Flash
- HEVC playback won’t be generally available for a long time
  - VP9 available now, for free, on three browsers with majority market share
- Adobe Primetime – will deliver HEVC to desktop, mobile and OTT, looks to be the most simple solution
How Will HEVC Play Out?

- Three main markets
  - Over the Top (OTT) – set top box/Smart TV – IP delivery
  - Streaming
    - Monetized content
    - Free content
OTT – UHD Sales Projections

- HEVC OTT market driven by UHD TV sets
- Not a lot of units to chase
Incompatibilities Exist

- Panasonic's AX800 UHD won’t play Netflix
  - No technical explanation given
- Some first gen sets may have Main only HEVC decode (not Main 10)
  - Not the problem with the AX800
  - Check decoder specs before buying close out brands
10-bit Color Coming

- Background:
  - Rec. 2020 – specifies 10-bit color space for UHD sets
  - Rec. 709 – specifies 8-bit color for HDTV
- Today, virtually all UDH sets use 8-bit Rec 709 compatible color space (only parts available)
- Hollywood pushing for Rec 2020, will ultimately push for all content with Main10 profile for 10-bit support

bit.ly/UHDdontbuynow
Push to High Dynamic Range

- Multiple specs bouncing around
  - Simulated Dolbyvision above right
  - Hollywood wants HDR as well before converting libraries
Can We Deliver 15 Mbps HEVC over the Internet?

- Netflix having to pay “peering charges” for high bitrate delivery
- Who can sustain 15 mbps for UHD?
- Will Netflix pass charges along?
  - Of course they will
  - bit.ly/HEVC_whowillpay
# Netflix Bandwidth Meter

## October 2014

<table>
<thead>
<tr>
<th>Rank</th>
<th>Change</th>
<th>Type</th>
<th>ISP Name</th>
<th>AVG Speed (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>Fios</td>
<td>VERIZON - FIOS</td>
<td>3.24</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Optimum</td>
<td>CABLEVISION - OPTIMUM</td>
<td>3.17</td>
</tr>
<tr>
<td>3</td>
<td>+1</td>
<td>House</td>
<td>BRIGHT HOUSE</td>
<td>3.13</td>
</tr>
<tr>
<td>4</td>
<td>-1</td>
<td></td>
<td>COX</td>
<td>3.09</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>CHARTER</td>
<td>3.08</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>COMCAST</td>
<td>3.05</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td>SUDDENLINK</td>
<td>2.96</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td>TIME WARNER CABLE</td>
<td>2.94</td>
</tr>
<tr>
<td>9</td>
<td>+1</td>
<td></td>
<td>MEDIACOM</td>
<td>2.92</td>
</tr>
<tr>
<td>10</td>
<td>-1</td>
<td></td>
<td>AT&amp;T - U-VERSE</td>
<td>2.86</td>
</tr>
</tbody>
</table>

http://ispspeedindex.netflix.com/usa
OTT Summary

- Two use cases, 4K and SD/HD to save bandwidth costs
  - 4K
    - Some services launching
    - Dedicated bandwidth necessary (your own pipes)
    - Content waiting Rec 2020/HDR
    - Not a lot of existing sets to target (and they will soon be obsolete)
    - HEVC/UHD services are launching in 2014
Big advances in 2015? What’s the Magic 8-Ball Say?
OTT Summary

- To save bandwidth?
  - Too few existing boxes that are HEVC capable
  - At some point, HEVC will become standard feature on STBs
    - 2016 maybe?
    - Hasn’t started yet
Any traction in 2015? What’s the Magic 8-Ball Say?
Streaming HEVC to Mobile and Desktop/Notebooks

- Premium content
  - Today - no free-general purpose decoder
    - Monetizable video, most likely via platforms like Adobe Primetime (by 2015)
    - Encrypted Media Extensions shows promise, but has some major issues
    - EME depends upon browser HEVC decode which isn’t there yet
    - Vast bulk of existing mobile market not HEVC capable (and/or has battery life issues, plus no players)
Lots of Premium Content to these Platforms in 2015?
Streaming HEVC to Mobile and Desktop/Notebooks

- Free content to these platforms?
  - Again, no players, just some movement
  - VP9 is a better alternative
To Be Clear

- HEVC is codec next
- Lots of applications today
  - Closed systems
    - Security, inflight, LTE,
    - Contribution,
    - Live event for transmuxing to H.264 and delivery
- But short term distribution to general markets?
Resources

- What is HEVC? (bit.ly/whatisHEVC)
  - Lots of links to technical resources
- The Future of HEVC: It's Coming, but with Plenty of Questions (bit.ly/HEVC_when)
- When Will the HEVC Royalty Picture Clear Up: Apparently No Time Soon (bit.ly/HEVC_royalties)
- VP9 Is Almost Here, But a Nokia Patent Fight Might Have it DOA (bit.ly/VP9_patent)
Questions