Introducing High Efficiency Video Coding: Breakthrough Benefits in Quality and Capacity for Operators

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Introduction

As the next generation of video compression, HEVC (high-efficiency video coding) has been at the center of attention across the entire video technology industry and promises to address a wide range of important technical and business issues.

This paper presents the benefits of HEVC and the challenges it is intended to address and describes HEVC from a technical perspective. It also provides a state-of-the-industry status report of how stakeholders across the video delivery ecosystem are adopting the standard and bringing it to market.

Even though low-cost ultra-high-definition TV sets and UHD programming are still some way off, there are compelling reasons to deploy HEVC compression and consumer devices right away—and consumers will notice the difference.

Industry Situation

Video has become one of the foundations of modern life and represents a huge percentage of the content that travels over broadband networks, from personal video conferencing on smartphones to anytime-anywhere content on any device. Cisco estimates that consumer IP video already represents more than 66% of all traffic on the Internet and will increase to 79% by 2018.

Video, of course, is also the primary purpose of a pay TV operator’s network. New content opportunities are knocking at the doors of pay TV service operators, but speed, capacity and reach limitations in their networks hinder their progress.

These limitations have fueled three transformations in the way video is delivered. The first has been to increase the amount of bandwidth available in carrier and operator networks. The second has been the embrace of Internet Protocol technologies. Unlike legacy cable and satellite distribution, IP distribution delivers only the streams being requested by consumers to the end device. Both of these advances make room for additional content and services.

The third big advance has been the emergence of more efficient video compression. A decade ago, when the most common compression method was MPEG-2, the distribution of standard-definition TV required at least 6 megabits per second. Early MPEG-4 compression enabled distribution of high-definition TV at about 10 megabits per second, although this has fallen to about 6 megabits per second, with good video quality. Only at that point did HDTV become truly practical.

Introducing HEVC: Next-Generation Video Compression

The next generation of video compression, known as high-efficiency video coding (HEVC, or H.265), promises to cut bandwidth requirements in half yet again and is ready to explode into the video delivery mainstream.

There is a widespread impression that the end-to-end ecosystem required for HEVC video delivery is still a few years away but, in reality, operators can implement HEVC sooner than the critics suggest. Deployable low-cost HEVC-capable set-top boxes are starting to ship, and other HEVC-enabling video infrastructure elements are already available.

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**Primary Benefits of HEVC**

HEVC represents a huge breakthrough, with several immediate benefits. The first and greatest benefit is that by using HEVC, pay TV operators can distribute a very-high-quality HD video picture at three to four megabits per second, which is about half the bandwidth needed for MPEG-4 video and a quarter of that needed for MPEG-2. This means that operators can make room for up to twice as many channels or for additional revenue-generating services.

Because HEVC reduces bandwidth requirements in transport and access, bandwidth-related upgrades in the network can be postponed. HEVC also enables 4G cellular broadband providers to distribute video to service territories that were previously considered marginal or unreachable using MPEG-4/H.264.

The second major benefit of HEVC is improved support for higher-motion programming. Programmers and technical experts believe that HEVC’s support for 60 fps progressive-scan video (p60) will become the primary requirement for action-oriented programming such as sporting events. Today’s HEVC set-top boxes support p60 video at HDTV resolutions of 720p and 1080p over an HDMI 1.4 interface.

The third big breakthrough of HEVC is more vibrant color. The 10-bit color available in HEVC is a more accurate color space than today’s 8-bit, with finer color gradients. One of the main reasons that consumers will be investing in new "ultra high definition" (UHD) TV sets will be for better color, and once they see it, they will be less likely to settle for 8-bit color when they buy. Eight-bit color will continue to be used for lower-quality distribution and mobile devices.

The fourth big benefit of HEVC—and the one that has garnered the most attention—is that HEVC makes practical the distribution of UHD television. UHD is often referred to as "4K," although UHD is actually a derivative of 4K, which is the digital cinema standard, with images in 4096 x 2160 4K pixel resolution. UHD is the consumer format with a slightly lower resolution of 3840 X 2160 pixels, and 8K with 7680 x 4320 pixels, designed for smaller screens.

The following figure highlights the differences between the new HEVC standard and the earlier video standards.

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**Figure 1: Comparing HEVC with earlier video format standards**

<table>
<thead>
<tr>
<th>Compression</th>
<th>MPEG-2</th>
<th>MPEG-4 (AVC)</th>
<th>Elemental HEVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-bit color, Bitrates (Mbps)</td>
<td>9.5 - 14</td>
<td>10 - 15</td>
<td>6 - 9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>18 - 25</td>
</tr>
<tr>
<td>10-bit color, Bitrates(Mbps)</td>
<td></td>
<td>10 - 18</td>
<td>&lt; 25</td>
</tr>
<tr>
<td>Format</td>
<td>720p60</td>
<td>1080i60</td>
<td>4Kp30</td>
</tr>
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<td>Horizontal x Vertical Pixels</td>
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<td>1920x1080</td>
<td>3840x2160</td>
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<td>Mpix/Frame</td>
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<td>1</td>
<td>8.3</td>
</tr>
<tr>
<td>Uncompressed Bitrate</td>
<td>1.125 Gbps</td>
<td>1.5 Gbps</td>
<td>6 Gbps</td>
</tr>
</tbody>
</table>

Source: Elemental Technologies

Yet another benefit of HEVC is that better compression will help offset any potential increases in distribution costs that come from the emerging practice of paid peering. Better compression results in smaller file sizes, which means that more content can be distributed using the same bandwidth as before.
**What Is HEVC Technically, and What Makes It Different?**

The worldwide standards for motion video compression are from the Motion Picture Experts Group (MPEG). Over the past two decades, the video industry has seen several successive generations of MPEG video compression standards, the most recent of which were identified in the table above.

The purpose of compression is to enable delivery of a satisfactory video stream while using less volume (or network capacity). If video were a liquid, it would be like providing a cupful of video, using a half a cup (or with HEVC, a quarter cup) of the volume.

To fully understand what makes HEVC different from the earlier MPEG-4 advanced video coding (AVC) and MPEG-2 standards, it is useful to know how MPEG compression works. Traditionally, a video stream is played at about 30 frames per second. In raw form (without compression), each video frame is delivered in its entirety. In order to accomplish compression, MPEG discards some of the video information in the video stream. MPEG’s next task is to determine which information to discard.

To do so, MPEG uses mathematical processes to estimate the motion of objects in the video, from one frame to the next, by comparing the contents of the video frames, and then keeping only the content that has changed.

**Figure 2: How MPEG compares video frames to estimate motion**

![Figure 2](image)

*Source: Elemental Technologies*

To provide a framework to compare frames, MPEG breaks down the video frames into four-sided blocks, called “macroblocks.” In MPEG-4/H.264, macroblocks can be square or rectangular, in sizes of 4x4, 4x8, 16x8 or 16x16 pixels. In HEVC, the equivalents of macroblocks are called “coding blocks,” which are always square and can be larger, ranging up to 64x64 pixels. The larger maximum size in HEVC means that fewer blocks are needed for the same area of video.

The figure below shows the difference between the structures of MPEG-4/AVC and HEVC frames.
Video encoding using MPEG compression defines three types of frames in a video stream:

- Index frames ("I-frames," which are also called "intra-coded frames"), which contain all of the data in a video frame
- Predictive frames ("P-frames"), which contain some reference data from previous video frames, and
- Bidirectionally predictive frames ("B-frames"), which contain some references from previous and subsequent frames

As long as the video player can accurately identify the I-frames, it does not need all of the visual information contained in the P-frames and B-frames in between in order to render the video accurately; it needs just the visual information that has changed. Only the differences between one frame and the next are transmitted.

MPEG compares the positions of the blocks from one frame to the next to determine which ones have moved and which ones have remained stationary, and then computes the direction of movement as a vector. While MPEG-4 (AVC) defines motion in eight X/Y-axis directions, HEVC uses 35 X/Y-axis directions. This allows motion prediction to be more accurate across multiple frames and helps to maintain high picture quality.
Ultra High Definition Is Coming, but Demand Will Take Time to Reach Critical Mass

Programmers and distributors have begun preparing to offer UHD programming as a way to differentiate themselves competitively. In the US, the ongoing battle between DirecTV and DISH Network will play out again, just as it did in the mid-2000s when each tried to out-do the other for the number of channels available in HD. But again, this will take time. The first live UHD TV demonstrations were very recent: transmission of the Osaka (Japan) Marathon in the fall of 2013. Also, for broadcasters and content providers, UHD will have an impact on everything from cameras and software to production practices. Satellite providers will need access to UHD transponders.

Game developers are also delivering UHD resolution, but support of UHD by game consoles is still on the roadmap and not in available products. Just as with the last big evolution to MPEG-4 and H.264, and to digital TV before that, all of these things will take time to put into place.

None of this diminishes the market potential for 4K and UHD. Ultimately, UHD will command a sizeable market ecosystem of its own:

- UHD content will command a premium, just as HD does now over SD, particularly for sports and special-event programming
- Advertising placed with UHD programming is likely to cost more
- Consumers will eventually upgrade from HD to UHD TV sets
- Broadcasters, studios and TV programmers will invest in 4K and UHD capture and production facilities

HEVC itself, as a technology, is not likely to be on the radar of consumers, other than as a checklist item for video compatibility, just as one needs a certain player to play content encoded with Microsoft Silverlight and PlayReady DRM.

So, despite the excitement that the industry has generated about UHD TV, it should be seen as a roadmap item, and not an immediate priority. 8K TV will come even later.

Separating UHD from HEVC Clarifies the Conversation

HEVC is as critical to the momentum of 4K and UHD (and online video delivery) as H.264 was for Blu-ray and HD broadcast. But because HEVC happens to be emerging during the same period of time as UHD, many observers have confused the two. People jump to the conclusion that because UHD will not be mass-market for some time, then neither will HEVC. Many casual observers think that they are synonymous, when in fact compression and resolution are two different concerns.

Because present-day HD TV sets are not UHD-capable, consumer demand for UHD will in fact take time to mature. For their part, the TV manufacturers have been showcasing the quality of UHD video, as well as innovations in industrial design, such as thin bezels and curved screens. Both are intended to make earlier HDTV adopters more receptive to make the purchase decision and replace their TVs. But many analysts believe that, given the penetration of tablets and large-screen smartphones, the era of the big-screen TV may have peaked.

But, specific to compression, the main concerns are the availability of HEVC video encoding and decoding, not the availability of UHD cameras or television sets. To take advantage of the efficiencies of HEVC, support for UHD isn’t necessary. The good news is that HEVC compression has been a key focus among video encoding suppliers for some time, and all of those major suppliers now have HEVC-capable products in trials.

Because video delivery involves so many elements, from capture to consumption, the perception within the industry has been that HEVC is a year or two away from mainstream availability. In reality, UHD will take longer to reach mainstream critical mass, while HEVC is ready now.
Why Will HEVC Be Successful, Unlike 3D?

In the end analysis, three factors will help HEVC reach critical mass. HEVC must enable more revenue, demonstrate an overall savings or, ideally, do both. The technologies to enable HEVC must be available at a cost that makes HEVC practical to deploy, and there must be demand for it.

Demand for HEVC will come from two places: operators and consumers. Conventional wisdom has been that consumer demand for UHD will force operators to transition to HEVC, but this is not likely to be the case because consumer demand requires availability of 4K content and affordable UHD TV sets.

Instead, the transition will be operator driven. The potential to reach more consumers over existing networks and to distribute more content at once without making big network upgrades will be more compelling to operators.

Operators have been skeptical of HEVC because many of them still remember the effort they put into launching 3D TV services, with little payback. 3D represents a new consumer viewing paradigm, requiring users to use special eyewear, which consumers did not buy. Also, there has been a lack of 3D content. The push for 3D came mostly from the hopes of technology suppliers that “If we build it, they will come,” and not from practical considerations.

When Will HEVC Be Available?

The prevailing myth about HEVC is that it is still in the distant future. This is far from the truth. In fact, technology suppliers and vendors from across the entire TV delivery ecosystem are poised to deliver.

- Semiconductor suppliers are already offering system-on-chip designs for HEVC TV set-top boxes, at costs that are already getting close to H.264 price points. Software decoding and HEVC mobile decoding chip sets are already available.

- There are several early adopter STB products with UHD; however, a bigger demand is likely to be HD STBs using HEVC. The second generation of UHD STBs will include features like HDMI 2.0 (with HDCP 2.2) and 802.11ac.

- For content streaming and caching solutions, trials and early adopters began emerging in 2014 and will be in the production mainstream in 2015.

- Most major TV headend (multichannel) suppliers have been demonstrating solutions since 2013 trials were announced in 2013 and 2014, with early adopters expected to deploy in 2015. HEVC will be fully mainstream in 2016.

- For cable/satellite multichannel TV, mainstream will arrive in 2016 or later.

- HEVC UHD for VOD and DTH delivery went into trials during 2014, will be deployed by early adopters in 2015 and will be mainstream in 2016.

- Smart TVs with UHD HEVC p60 decoding will begin shipping later in 2014.

Operators making infrastructure plans today will be able to deploy production-ready HEVC technology sooner than they may realize.

Summary: HEVC Holds the Keys to the Future

Support for HEVC compression will enable operators to put more content and services through their networks and deliver higher video quality, irrespective of the resolution of the video (e.g., 4K), and this is the path that the video infrastructure suppliers have been taking.
Chip vendor Sigma Designs puts it succinctly: HEVC responds to the operator's economic requirement, which is to reduce the per-megabyte cost of delivering video to the consumer. And to the consumer, HEVC promises new video features including high dynamic range and better temporal resolution, and not just more pixels.

HEVC summary:

- HEVC will be the preferred replacement video codec for AVC regardless of resolution
- HEVC promises dramatic improvements in the accuracy, speed and quality of digital video
- HEVC can cut distribution and CDN bandwidth requirements in half, in comparison with AVC
- HEVC device support is accelerating

Dune HD promises to be in the thick of the action!

**Dune HD TV-204 with HEVC Support—Introduced in 2014**

Dune HD promises to be in the thick of the HEVC action! Dune HD introduces the first full-featured set-top box to support HEVC in 2014. With HEVC support, the Dune HD TV-204 provides operators a more cost-effective and efficient means to deliver content into the home. Because HEVC-encoded content is expected to be 50% smaller than comparable H.264/AVC files, the TV-204 allows bandwidth savings for operators and streaming service providers.

The TV-204 supports up to full HD resolution and many streaming formats, containers and technologies; DRM/CA systems from Verimatrix and other leading technologies; and popular Web interfaces, WebKit and HTML5. Dune HD offers flexible middleware integration options and highly competitive prices.

Operators can sample the Dune HD TV-204 by contacting info@dune-hd.com.

**About Dune HD**

Dune HD is a global leader in high-definition media players and connected boxes for consumers and operators. Over the past five years, Dune HD has received more awards than any other company in the category for universal media players. Dune HD products support a wide number of digital formats, from Internet-based digital streaming and download to disc-based formats such as 3D, Blu-ray and DVD, along with supporting IPTV, VOD and OTT. Designed by world-class engineers, Dune HD media players are enjoyed by more than half a million consumers in more than 60 countries. Learn more at www.dune-hd.com.