Kevin Jakel <kevin@unifiedpatents.com>

Can AV1 and HEVC just get along?

1 message

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What will TV cost you? Putting a price on HEVC licences

Changes in how you watch movies, stream TV and use video chat are on the way. These will fundamentally affect the economics of how content is delivered to you, as well as the way that the patents underpinning the enabling technology are licensed

By Erik Oliver and Kent Richardson

The compression algorithm is a piece of critical technology that enables users to view videos on a phone or a computer and now there is a new one coming our way: HEVC.

How important is the commercial adoption of this new compression technology? Without compression, the movie *Thor: Ragnarok* – which is 130 minutes long – would be 11.6 TB. With current compression technology that same movie is about 27 GB; with HEVC it is approximately 14 GB (see Figure 1). Thus, HEVC can help consumers to save limited mobile data and businesses to cut costs on data storage and transmission. All while delivering equal – or better – quality video.

However, there is no point pretending that compression technology is easy. The math makes your head spin, the trade-offs are tortuous and the metrics to decide what looks good – whatever that means – will make you question why you ever asked. The implications for chip designers are staggering. Hundreds of billions of dollars of semiconductors are produced with specially designed circuitry and instructions for optimising video compression and decompression. Those semiconductors are built into billions of devices every year. How much circuitry are we talking? We estimate that for 2018, if you divide up all the transistors manufactured for video compression, there would be 4,000 transistors per ant. (There are about 5 quadrillion ants in the world.)

Broad industry adoption of HEVC was kickstarted by Apple's July 2017 announcement that its iOS 11 would natively support HEVC. Apple's membership of AOMedia became public as of the time of writing. It is too early to tell whether this membership will cause Apple, and others, to shift away from HEVC adoption.

There are multiple reasons for slow adoption but a complex and expensive patent licensing landscape with three major licensing groups may be one. Compared to a peak price of $0.20 per handset for an AVC patent pool licence, a consumer electronics manufacturer planning to make a handset that supports HEVC would be facing an estimated $1.60 per handset charge to license HEVC from the three pools. There would also be additional royalties for owners of non-pooled patents, which we estimate would bring the bill to $2.25.

One possible reason for the proliferation of licensing groups is that historically, licensing patents around audio/video compression has generated billions of dollars in revenue. Further, the patent battles are slated to continue with the latest HEVC standard. If your company plans to support HEVC, this will be complicated. Solvable but complicated.

This article aims to provide an understanding of the history of HEVC, video compression standards and the associated patent licensing landscape. Given the complexity of this subject, it focuses on providing a starting point to guide companies through some of the relevant patent licence issues. We are not playing favourites among the pools nor are we criticising any one pool or its policies. Rather we have focused on the perspective of HEVC adopters – the customers of the pools. How will they view the pool's stated rates and policies? With that, we will look at how the pools, their pricing and the licences might affect adopters' profits and costs.

Brief history of video compression

While HEVC is the sixth major ITU standard for video compression, it is also the third video compression standard jointly worked on with the MPEG (operating under the ISO and the IEC). Table 1 provides a brief overview of key video compression standards from the ITU and MPEG.

Each of these standards has targeted delivery video at lower bandwidth requirements, generally at significantly higher quality. MPEG-2 was notable for its adoption as the standard format for digital TV broadcasting and in DVDs. HEVC has now been adopted for the next generation of digital TV broadcasting (ATSC 3.0 in the United States). Table 2 highlights several technical improvements between most of the successive video standards discussed in Table 1.

Each of the standards builds heavily on those that came before. Thus, the 2013 HEVC standard does not stand alone; rather, many of its fundamental concepts relate to the approaches selected for H.261 back in 1988 – which provides its own set of patent licence challenges. For example, HEVC builds on the macroblock concepts that date back to the 1988 H.261, while adding new, more refined capabilities for segmenting those macroblocks. For those interested in a more in-depth technical analysis of the standards, the presentations and papers by Gary Sullivan are a good starting point (see Google Scholar: https://goo.gl/QrNzhA).

One further point: standardisation is critical to the technology industry and the video encoding space in particular. By standardising the video encoding stream, more devices can interoperate, which leads to the promised value highlighted by Intel's former CEO, Craig Barrett: "[w]hen you have common interfaces,

Glossary of abbreviations and key terms

- AOMedia: the Alliance for Open Media.
- ASP: average selling price.
- ATSC: Advanced Television Systems Committee, developer of standard for over-the-air digital television in the United States.
- AVC: advanced video coding, alternatively H.264 or MPEG-4 (part 10).
- FRAND: fair, reasonable and non-discriminatory.
- HEVC: high efficiency video coding, alternatively H.265 or MPEG-H (part 2).
- HEVC Advance: private company – HEVC Advance LLC – based in the United States that serves as a patent licence administrator for an HEVC pool.
- ISO: the International Organisation for Standardisation.
- IEC: the International Electrotechnical Commission.
- ITU: the International Telecommunication Union.
- LTE: long-term evolution technology.
- MPEG: the Moving Picture Expert Group.
- MPEG LA: a private company – MPEG LA, LLC – based in the United States that serves as a patent licence administrator for many pools, including the MPEG-2 pool, the AVC pool and an HEVC pool.
- NDA: non-disclosure agreement.
- NTSC: the previous US standard for analogue broadcast TV, named after the National Television System Committee.
- SEP: standard-essential patent.
- US Patent and Trademark Office.
- VC-1: a standard originally developed by Microsoft for Windows Media Video 9 but standardised by the Society of Motion Picture and Television Engineers (SMPTE) as SMPTE 421; it is also supported by Blu-Ray discs.
- Velos: a private company – Velos Media LLC – based in the United States that serves as a licensor and licence administrator for an HEVC pool.

common protocols, then everyone can innovate and everyone can interoperate. *Companies can build their businesses*, consumers can expand their choices, the technology moves forward faster, and *users get more benefit*" (emphasis added). Contrast this with the problem of incompatible technologies where hardware for one format (eg, Betamax or HD-DVD) could not work with another (eg, VHS or Blu-ray). It is expensive for content providers and others in the ecosystem to support multiple formats. It is generally preferable to have fewer divergent standards, as well as higher-quality standards.

We will provide a brief history of video patent pools before turning to the compression capabilities of each of these video compression standards, as well as known licensing fees of established pools, in the context of the ever-changing consumer electronics landscape.

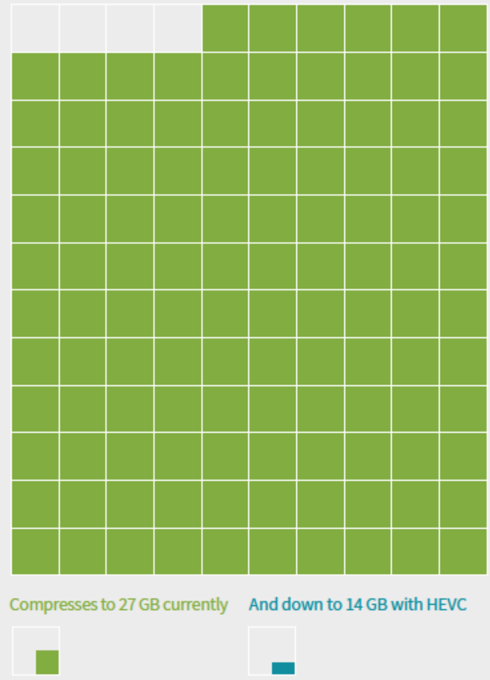
TABLE 1. Overview of key video compression standards

Standard	Publication year*	Commentary
H.120	1984	Early compression technique, not widely adopted.
H.261	1988	Often viewed as basis of modern video compression techniques.
MPEG-1	1993	Inherits many features from H.261 while adding several technical features.
H.262/MPEG-2	1995	Used in DVDs and broadcast digital TV, high similarity to (MPEG-)1.
H.263	1996	Many similarities to MPEG-1 and H.261 with enhanced capabilities. Used in videoconferencing systems. Interrelated to MPEG-4 (Part 2) (1999), which has H.263 baseline with additional features.
H.264/MPEG-4 (Part 10)/AVC	2003	First test models in 1999; drafts in 2002; widely adopted on the Internet and mobile devices, as well as Blu-ray players.
H.265/MPEG-H (Part 2)/HEVC	2013	First test models in 2010; drafts in 2010-2012; selected for use in next-generation digital TV (eg, ATSC 3.0).

* Publication year of first version of standard by ITU (or ISO)

FIGURE 1. Video compression reduces data requirements by 1,000x

Thor: Ragnarok, a 130-minute uncompressed movie, 11,600 GB:



Video patent pools: history

While HEVC is the sixth major standard from the ITU, it is the third major video coding standard to have a patent pool associated with it. The first – MPEG LA's MPEG-2 pool – was notable for being widely adopted (it was used in digital TV – including the ATSC standards in the United States – and also used in DVDs). MPEG LA provided a one-stop shop for clearing the overwhelming majority of patent rights for use of MPEG-2. For decoding hardware products (eg, a TV, DVD player or computer), the rates were:

- $4.00 (inception in approximately 1997 to 2002);
- $2.50 (2002 to 2010);
- $2.00 (2010 to 2015); and
- $0.50 or $0.35 (2015 onward).

The rates and pricing remain controversial. For example, in August 2017, Haier – a large consumer electronics maker and an ATSC and MPEG-2 licensee of MPEG LA – filed suit over the rates (see *Haier America Trading LLC v Samsung*, Case 1:17-cv-921, NY Northern District, August 21 2017 – the suit covers both the ATSC and MPEG-2 patent pools operated by MPEG LA). The *Haier* suit raises questions about the (lack of) effectiveness of the screening process for including patents, inclusion of non-essential patents, the pricing model (flat fee versus scaled by device cost, especially in the face of declining device costs) and antitrust concerns.

One of the complaints in *Haier* concerns the addition of patents to the pools over time. This will not surprise astute observers of the video standards world. NTSC encoding for analogue TV signals in the United States was first promulgated in around 1941 (for black and white TVs) and then modified in around 1953 to add colour. Nonetheless, patent licensing for improvements on NTSC had a much longer life than 20 years, even given the addition of colour.

Nonetheless, the fact that there are live patents after more than 20 years should raise questions that require answers from patent owners. Thus, even MPEG-2 – which is now over 20 years old – was not completely unencumbered by patents in 2017. MPEG LA continues to run a licensing pool for MPEG-2 that included seven unexpired patents as of July 2017 and charged $0.50 per device for a patent licence (notably, the remaining patents have early priority dates in this case but greater than their 20-year lives due to country-specific laws in the United States, Malaysia and the Philippines). A lower-priced $0.35 tier is also available for companies that waive early termination rights.

The issue of listing patents with priorities post-dating the standard can be at least partially answered: standards are not fixed in time. Even the MPEG-2 standard has been amended since its 1995 release, with the most recent amendment dating from 2012. Also, the vast majority of patents historically in the MPEG-2 pool had priority dates falling roughly between 1990 and 1995. Thus, any late patents may actually represent innovations related to amendments to the standard.

Turning away from MPEG-2, we arrive at the second widely adopted video coding standard: AVC.

MPEG LA also served as the administrator for the AVC patent pool. The rate is $0.20 per device but there are some volume-based pricing tiers, as well as a cap on total licence fees. Compared to MPEG-2, the AVC patent pool was more affordable. (See "Other issues" boxout for a discussion on whether the AVC pool rate was set artificially low.)

Bear in mind that if your device supports multiple standards, you will need to license each one separately. So for a device that supports MPEG-2, AVC and HEVC together, you would need to pay the fees for each separately to the appropriate administrator(s) or independent patent owners.

Before exploring the HEVC patent licensing landscape in more detail, the backdrop of the changing consumer electronics landscape merits investigation.

Consumer electronics: pricing and performance under Moore's Law

Discussing video compression standards without reference to the changing consumer electronics landscape can be challenging. Consumer electronics, particularly computers, exist against the backdrop of Moore's Law which, loosely speaking, predicts that computing capabilities double in performance every two years.

Figure 2 shows trends for computer prices from 2002 to 2015. The downward pressure on personal computer prices – even in the face of inflation – is extreme, with the price of a computer dropping from $1,000 to $277 from AVC's launch in 2003 to HEVC's launch in 2013. Significantly, a $277 computer bought in 2013 is significantly more powerful than its more expensive 2003 predecessor. Figure 3 shows the processor performance over the period from 2002 to 2015 in millions of instructions per second (MIPS). Around the time that AVC was launched, processors were clocking it at about 10 MIPS, but by the time of HEVC's launch 130,000 MIPS processors were readily available. Thus, over the same 10-year period where the computer dropped in price by nearly one-quarter, the processing power available went up by a factor of 10,000.

TABLE 2. Key improvements of major video standards

H.261	MPEG-1	H.262/MPEG-2	H.263	H.264/AVC	H.265/HEVC
• Macroblock motion compensation • Discrete cosine transform • Scalar quantisation • Zig-zag scan • Run length • Variable-length coding	H.261 features plus: • Bi-directional motion prediction • Half-pixel motion • Slice-structured coding • DC-only 'D' pictures • Quantisation weighting matrices	MPEG-1 features plus: • Interlaced-scan support • Improved DC quantisation precision • Scalability (SNR, spatial, breakpoint) • I-picture concealment motion vectors	H.263 plus MPEG-1/2 features plus: • 3D variable length coding of DCT coefficients • Median motion vector prediction • Optional, enhanced modes	H.263 features plus: • Coding efficiency enhancements • Error resilience • Segment coding of shapes • 0-tree wavelet coding of still textures • More (including optional features)	H.264 features plus: • High-level structure, segmentation and transformation options • Intra-/Inter-picture prediction and entropy and transform coding changes • More (including optional features)

Sources: Adapted from presentations by Gary Sullivan, co-chair for ITU-T VCEG, in "Overview of Intl Video Coding Standards", July 2005 and "Developments in Video Coding Standardization", February 2015

TABLE 3. AVC and HEVC licence rates and estimates

Standard	AVC	HEVC			
Licensing group	MPEG LA	MPEG LA	HEVC Advance	Velos estimate	Total estimate
Number of WW Patents	3,704	4,417	3,321	3,200	10,938
Handset royalty ($) – highest rate	$0.20	$0.20	$0.65	$0.75	$1.60
$ per 1,000 patents for handset	$0.05	$0.05	$0.20	$0.23	$0.27
Handset cap	$10 million	$25 million	$30 million	Unknown	$55 million plus
Sample total royalty for 10 million units	$1.5 million	$2.0 million	$6.5 million	$7.5 million	$16.0 million

Sources: MPEG LA and HEVC Advance websites as of January 2018 combined with estimates for Velos as discussed below. As Samsung and ETRIs patents are currently in both MPEG LA and HEVC Advance pools until 2019, adopters paying for both pools will receive a credit and only pay for the patents once

Video compression basics

Audio and video compression use mathematical techniques to achieve significant savings in file sizes. This quick summary focuses on the video component. Uncompressed video is made up of multiple still frames – these frames are the starting point for compression.

- Each still frame can be broken into smaller blocks. The visual imagery in those blocks can be estimated or compressed using complex mathematical equations. This is lossy compression – the reconstituted still image will not be identical to the source still image.
- The blocks themselves can also be compared for similarities and redundancies eliminated, thus providing further compression. For example, a blue sky in the background will have a lot of redundancy.
- Next is handling motion – if you start looking at the differences between two successive frames of a moving picture, there is often little change from frame to frame. Thus, if the movement of the handful of blocks with changes can be estimated, it is not necessary to retransmit the whole compressed frame but rather just the heavily changed blocks and the movement of blocks.

This is a quick, not-too-mathy summary of the fundamentals of video encoding. The downside is that it might leave you scratching your head: why or how do newer compression standards do better than older ones? The answer is in the details. Briefly: HEVC offers more flexibility or uses different mathematical compression approaches than AVC at each step to enhance the amount of redundancy that can be identified and compressed out.

Figures 2 and 3 together translate the dilemma for consumer electronics manufacturers operating in the environment of Moore's Law into economic terms: deliver laptops, mobile phones and tablets with twice the computing power for lower prices year after year after year. While we do not show the graphs for this, the storage capacity of computers and network bandwidth across the network has been following a similar curve.

It is worth contrasting this with expectations for higher-resolution video over that same period (eg, from 1080p in 2003 to, say, 8K presently). The 1080p video would be 1,920 x 1,080 pixels, while the 8K video is 7,680 x 4,320 pixels. So that is a factor of 16 times more pixels per videoframe; in fact it is slightly higher due to increased bit depths.

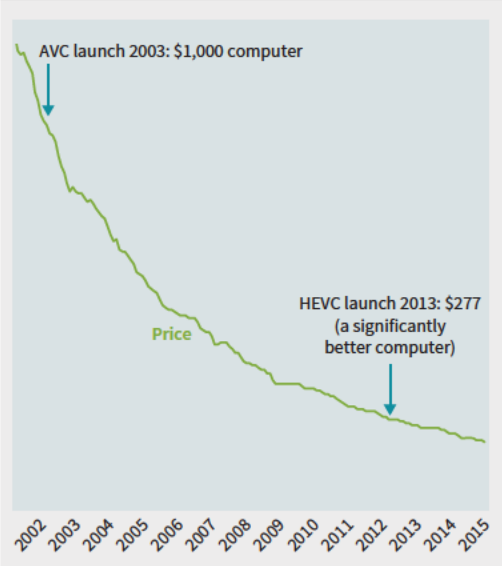
Against this backdrop, what does the patent and licensing landscape for HEVC look like?

HEVC licensing demands

The known public demands (and estimates) for licence fees for AVC and HEVC are summarised in Table 3. We know that some of the public data is inaccurate or out of date (see "Moving target analysis" boxout). Nonetheless, for this analysis we will use the public data as is (data retrieval dates are noted), even though that may skew the estimates slightly. Relatedly, while Velos's data is not publicly available, we have estimated its holdings and royalties, as discussed further below. Also, given the relative newness of HEVC as a standard, there are still pending patent applications around the world that are not yet reflected in the pool's lists.

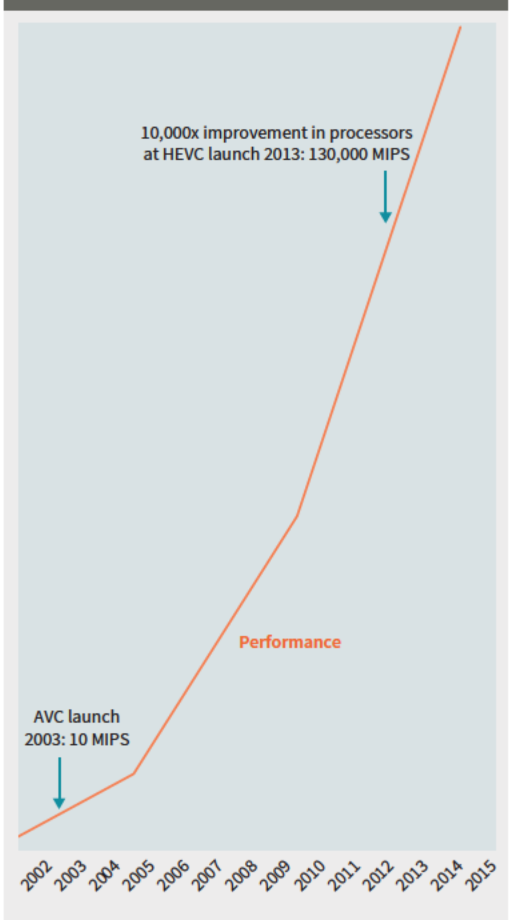
We analyse the rates through several different lenses in Table 3 to provide context on how the different rates, caps and patent holdings interact with the pricing. Thus, compared to a peak price of $0.20 per handset for the sole AVC pool, a consumer electronics manufacturer

FIGURE 2. Computer prices 2002-2015



Source: US Bureau of Labour Statistics: "Long-term price trends for computers, TVs, and related items" (The Economics Daily, October 13 2015)

FIGURE 3. Computer performance 2002-2015



Source: Millions of instructions per second (MIPS) data from Intel, AMD and Wikipedia

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