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**Abstract**

This information contribution contains a survey of deployed products and services using the HEVC standard and the formal specifications in which it is supported, along with a brief introduction to the standard written for broad readership. Revision marking is included to show changes relative to JCTVC-AL0020-v2 of January 2020.

**Introduction to the HEVC standard**

The HEVC standard (formalized as Rec. ITU-T H.265 and ISO/IEC 23008-2) was first approved and published in 2013 [1][2][3]. Its compelling advantage is that it can achieve roughly double the compression efficiency of the previously-dominant H.264/MPEG-4 AVC standard – enabling, e.g., the storage of twice as much video content in the same storage space with the same video quality, a doubling of channels in a broadcasting service, halving the bit rate needed for sending video on a network, or alternatively providing a major increase in video frame quality, frame rate, or picture resolution (when using a sufficiently powerful encoder) [4][5]. The need for maximal compression efficiency for video is pressing and urgent, since about 80% of the data transmitted on world-wide networks is video, and that percentage has been steadily growing and is projected to continue to grow further [6].[[1]](#footnote-1) The introduction of ultra high definition (UHD), high dynamic range (HDR), wide color gamut (WCG), and high frame rate (HFR) video services have increased the challenge with their use of larger frame sizes, faster refresh rates for progressive-scan video, and greater pixel bit depth.

The complexity requirements for implementation of HEVC decoders are relatively modest (less than twice the complexity of a comparable AVC decoder), and HEVC encoders, while being somewhat more of a challenge, are also quite feasible and are vendor-customizable and generally less cost-sensitive.

**Overall HEVC deployment statistics**

Some published deployment statistics have been as follows:

1. Most personal computers and mobile handset devices and essentially *all* 4K UHD televisions have included HEVC support since 2015 [7][8][9]. Once 8K UHD consumer televisions were later introduced (around 2019 or 2020), essentially all of those have included HEVC support as well [10][11][12].
2. A report by Digital Tech Consulting in March 2016 [8] contained the following estimates of numbers of devices shipping with HEVC support and subscriptions to services with access to HEVC content:
   1. 20 million televisions and 313 million mobile handsets in 2015
   2. 948 million devices to ship in 2016, rising to 2.6 billion in 2020
   3. 67 million service subscribers in 2016, rising to 300 million in 2021
3. As of September 2017, a developer survey by Bitmovin with 380 respondents from more than 50 countries (primarily with technical roles, roughly evenly providing live and on-demand video services) reported [13]:
   1. 28% of video developers “currently using” HEVC
   2. 40% of video developers “planning to use [HEVC] in the next 12 months”
4. As of December 2017, a survey Unisphere Research and *Streaming Media* (sponsored by Harmonic) with 437 complete responses (primarily in North America) reported [14]:
   1. 25% of respondents currently using HEVC
   2. 62.5% of respondents considering using HEVC by the end of 2018
5. In April 2018, HEVC was reported by Thierry Fautier of Harmonic to be supported in more than 2 billion devices [15].
6. In June 2018, in a survey by Unisphere Research and *Streaming Media* (sponsored by Beamr and Help Me Stream) with 406 responses, 66% of video encoding industry respondents said they were either using HEVC in their current production pipeline (11% in operation, 12% in pilot projects) or were taking steps toward using it within two years [16][17].
7. As of August 2018, ScientiaMobile reported statistics for video capabilities on mobile devices, saying that 78% of usage of iPhones and 57% of usage of Android smartphones involved devices with hardware support for HEVC decoding [18].
8. As of September 2018, a developer survey by Bitmovin with 456 respondents from 67 countries (primarily with technical roles, roughly evenly providing live and on-demand video services) reported [19][20]:
   1. 42% of video developers “currently using” HEVC
   2. 36% of video developers “planning to use [HEVC] in 12 months”
9. As of September 2019, a developer survey (conducted from 10 June to 5 August 2019) by Bitmovin with 542 respondents from 108 countries (primarily with technical roles) reported [21]:
   1. 43% of video developers “currently using” HEVC
   2. 32% of video developers “planning to implement within the next 12 months”

**Identified deployments of HEVC**

The basic deployment situation for HEVC in available product offerings is summarized as follows:

1. **Broadcast and streaming services and devices**: HEVC has been included in many deployed industry television broadcast and streaming services:
   1. **Austria** is using HEVC (in **DVB T2**) for digital terrestrial broadcasting [23], and **Telekom Austria** has switched its **direct2home** pay-TV service for **Czech Republic** and **Slovakia** to HEVC [24].
   2. **Brazil**’s streaming service **Globo.com** uses HEVC for 4K UHD streaming, as of February 2017 [25].
   3. **China** has a new 4K UHD broadcast network by **China Telecom Sichuan** and **Huawei** using HEVC, as of late 2014 [26].
   4. **Croatia** has a full transition to HEVC in **DVB-T2** under way with completion planned in 2020. The regulatory authority surveyed free-to-air DTT broadcasters, receiver manufacturers, and distributors in 2015, and concluded that “the questionnaire results clearly show[ed] that H.265/HEVC is the best choice for future DVB-T2 networks in Croatia” [27]. (DTT is a common way of viewing television in Croatia, with about 50% households watching DTT on their receivers.) The HAKOM regulatory authority announced the selection of DVB-T2 with HEVC in March 2016 [28]. The country started HD broadcasting using HEVC in late 2019, and planned a full transition with simultaneous support for all television programmes to use the new system in 2020 [29]. By March 2020, the DVB-T2/HEVC system covered 97% of the Croatian population and the completion of the full transition was scheduled for late 2020 [30].
   5. **France** has **Free**, an IPTV service provider offering 10 bit 4K UHD, launched in 2015 [31][32].
   6. **Germany** is now using HEVC (in **DVB T2**) for *all* HD and higher-resolution terrestrial broadcasting [23][33]. This is the first terrestrial broadcasting with HD or higher resolution in Germany. The use of the previous-generation DVB-T formats in major markets ceased in a switch-over effective 29 March 2017 [34]. The **Freenet TV** service offers commercial subscription services on the terrestrial broadcasting system [34] and the same channels are offered by satellite direct-to-home service as of March 2018 [35]. **Sky Deutschland** is using HEVC for UHD, including live programming, as of late 2016 [36]. **Astra HD+** began UHD service with HEVC in 2015 [37]. **Vodafone** has a new **GigaTV** platform with 4K UHD over cable using HEVC since early 2017 [38][39].
   7. **Hungary** is launching HEVC (in **DVB T2**) for digital terrestrial television broadcasting by Antenna Hungária Zrt in 2020 [40][41].
   8. **India** has **Tata Sky** using HEVC for 4K UHD since 2015 [42], **Videocon d2h** using HEVC for HD satellite direct-to-home broadcasting since 2015 [43], **Sun Direct DTH** using HEVC since 2016 [44], and **Airtel** using HEVC up to 4K UHD at 60 fps [45].
   9. **Iran** has begun terrestrial broadcasting using HEVC (Main 10 profile with 1080p resolution) by the national broadcasting company **IRIB** using DVB-T2 with support for HbbTV. Trials began in October 2017 and broadcast service began in 2018 [46].
   10. **Italy** has begun terrestrial broadcasting of all content in the HEVC format and disallowed the sale of TVs using the prior DVB-T/MPEG-2 or AVC formats, as of January 1, 2017 [47]. It also has the **Chili** OTT TV service using HEVC for 4K UHD (since 2015) [48].
   11. **Japan** has commercial 4K 60 fps HEVC broadcasting by **SkyPerfect JSAT** (since 2014) [49], the **Cable 4K** television service launched in December 2015 by a consortium of 39 Japanese companies including **J:COM** [50][51], 4K/8K satellite broadcasting service launched by **NHK** and commercial broadcasters via B-SAT in December 2018 [52][53][54][55][56], 4K UHD trials on the **NTT Plala Hikari TV** streaming service (trials since 2014) [57], and the **d animestore** HEVC streaming service for cartoons by **Docomo** (demonstrated in 2014 and deployed shortly thereafter) [58][59].
   12. **Korea** began over-the-air broadcasting of **ATSC 3.0** using HEVC in February 2017, including roll-out of UHD 4K and HDR [60][61][62], **KT** and **SK** both launched broadband UHD services based on HEVC (in 2016) [63], and **t-broad** provides 4K and 8K UHD over broadband IP [64].
   13. **Netherlands** has announced a plan to switch its entire terrestrial broadcast system to HEVC (in **DVB T2**) by April 2019 [23].
   14. **Portugal** has the **Portugal Telecom** 4K UHD service using HEVC since 2016 [65] and the **NOS** broadband and pay-TV service using HEVC for 4K UHD since 2016 [66].
   15. **Russia** has the **NTV-Plus** satellite direct-to-home broadcasting service launched throughout the country in April 2017 using HEVC with 4K UHD, following trial broadcasting begun in 2014 [67][68].
   16. **Spain**’s **Digital TV Tech Forum** has adopted HEVC for HD and UHD streaming, as of August 2016 (using HbbTV 2 version 2.0.1) [69].
   17. **South Africa**-based **Showmax** added HEVC support in March 2019 [70].
   18. **Switzerland**’s **Swisscomm** launched UHD service with HDR in 2016 using HEVC [71][72][73].
   19. **UK** has **Sky Q** UHD with HEVC [74][75], **BT** sending UHD with HEVC for live satellite broadcast [73][76] the **Freeview Play** broadcast & IPTV hybrid service using HEVC with HDR [77][78], and the **Virgin Media** cable service with 4K UHD [79].
   20. **U.S.**-based services using HEVC include **Amazon Instant Video** and **Fire TV** (using HEVC since 2014 [80][81]), **Netflix** (using HEVC since 2014 [80][81]), **Dish Network** (using 4K 10 bit HEVC up to 60 fps for UHD) [82][83], **DirecTV** (using HEVC for 4K UHD OTT+DTH service since late 2016 [84][85]), **Edge Networks’ Evoca** subscription service using **ATSC 3.0** with HD and 4K UHD [86], **Hulu** (using HEVC for its 4K UHD service since late 2016 [87]), **Vudu** (using HEVC for 4K streaming since early 2017 or sooner [80][81]), **FandangoNow** (formerly **M-Go**, using HEVC for UHD streaming [81]), **Layer3 TV** (launched in 2016 based on HEVC) [88], **Microsoft Movies & TV** (using HEVC for UHD since 2016), **Ultraflix** (using HEVC for 4K streaming [81]), **Sony Ultra** (began 4K UHD streaming with HEVC in April 2016 [81][89]), and **SES** offering 10 channels of 4K UHD service with 2 cable operators contracted and more than 20 cable operators participating in tests (as of April 2017) [90][91]. **LiveU**, which produces technology for live television streaming services, announced in December 2018 that HEVC had reached 25% deployment penetration in its services [92] and in December 2019 that its HEVC usage had grown to include nearly 50% of its field units used to stream sports [93][94]. **Encoding.com**, which provides encoding services for the video streaming industry, has issued reports describing its encoding work for OTT service providers that include some of the largest streaming service providers, and reporting 9% usage of HEVC in 2017 [94][95] and 12% usage of HEVC in 2018 [94][96].
   21. **Dish HD Asia** offers an all-HEVC HD and UHD 4K service across **Asia** since 2016 [97].
   22. **Eutelsat** launched 4K UHD channels across **Europe**, the **Middle East** and **Africa** using HEVC in January 2017 [98].
   23. **Liquid Telecom** launched an SD and HD direct-to-home satellite TV service using HEVC in eastern, central and southern **Africa** in 2016 [99].
   24. **Kartina TV**, a Germany-based OTT provider targeting speakers of **Russian** around the world, launched a system in 2015 using HEVC that can deliver 150 SD and 30 HD channels, sourced primarily from countries located around the **former Soviet Union** [100].
   25. **Sports event broadcast and streaming offerings** have highlighted the use of HEVC in 4K UHD with live streaming and satellite broadcast, including the **2014 Winter Olympics** [68], the **2014 FIFA World Cup** [101], the **2015 Cricket World Cup** [42], the **2015 UEFA Champions League Football** **Final** [102], the **2016 Summer Olympics** [103], **NASCAR** [85], **NBA** [85], **MLB** [85], **Premier League Football** [74][75][104], and **F1 Racing** [74][75].
   26. **Samsung Galaxy S4** through **S8** phones have supported HEVC with full HD quality since the Galaxy S4 in early 2013 [105].
   27. **LG**’s **G4** (2015), **G5** (2015), and **G6** (2017) phones support HEVC with UHD resolution [106], and the G5 and G6 support 10 bit video and 60 fps HFR [107].
   28. **Microsoft** released **DirectX Video Acceleration** (**DXVA**) hardware acceleration API for HEVC in August 2013 [108], and **Windows 10** and **Internet Explorer** and the **Edge** browser (released in 2015) include HEVC support when hardware acceleration is available in the graphics hardware (which is generally available in new devices) [109]. Windows 10 includes an HEVC decoder API as a **Media Foundation Transform** for use by third-party applications [110]. Encoding as well as decoding is supported for **Universal Windows Platform** (UWP) applications for the **Windows Desktop**, **Mobile**, **IoT Core x86**, **IoT ARM**, and **Xbox** [111]. The **Xbox One** has supported 10 bit HEVC decoding with 1080p HD at 60 fps HFR since 2015 [112]. The **Xbox One S** has supported HEVC with 10 bit UHD, HDR, and 60 fps HFR since 2016 [113]. The **Xbox One X**, announced for late 2017, additionally supports HEVC *encoding* with UHD resolution at 60 fps HFR. The 5th generation **Surface Pro** laptop/tablet device (2017) supports hardware-accelerated 4K HEVC decoding [114]. The **Microsoft Movies & TV** OTT service has been serving UHD content using HEVC since November 2016.
   29. **Roku** streaming set-to box devices have supported HEVC 4K streaming at up to 60 frames per second since 2015 [115][116].
   30. **Apple**’s **macOS High Sierra** (version 10.13, released to developers June 2017) supports HEVC, integrates it into its apps such as the **Safari** browser and **Final Cut** video editor, and uses it as its default video storage format [117][118] Hardware support for HEVC is included in the current **MacBook** and **MacBook Pro**, and older devices running High Sierra will also support the format [117][118]. **iOS 11** for the **iPhone** and **iPad** (released Fall 2017) also uses HEVC as its primary video format and also for still images and “Live Photos” based on the HEIF file format with HEVC [119][120][121]. **tvOS11** and **Apple TV** has included 4K HEVC support with HDR since 2017 [122].
   31. **Google’s Android** 5.0 (December 2014) includes APIs for HEVC (including UHD support), and Google’s **Chromecast Ultra** media player includes HEVC support (November 2016).
   32. **Raspberry Pi 3**, a low-cost computer device of the Raspberry Pi Foundation (released in 2016) had some capability for HEVC decoding, and the **Raspberry Pi 4** (released in June 2019) includes 4Kp60 hardware decoding capability [123][124].
   33. **GoPro Hero 6 Black** (April 2018) and **Hero7 Black** (September 2018), action camera devices, include HEVC encoding with UHD support at up to 60 fps HFR and full HD support at up to 240 fps HFR [125][126][127].
   34. **Fujifilm X-T3** (September 2018), a mirrorless interchangeable-lens camera, supports HEVC recording up to 4k 10 bit UHD at 60 fps with 4:2:0 [128][129][130][131].
   35. **Canon XF705** (September 2018), a professional-grade camcorder, supports HEVC recording up to 4k 10 bit UHD at 50 fps with 4:2:2 and HDR (either HLG or PQ) [132][133][134].
   36. **Panasonic AG-CX350** (January 2019), a hand-held fixed-lens camcorder, supports HEVC recording up to 4K 10 bit UHD at 50 and 60 fps with HLG HDR [135][136]. **Panasonic Lumix DC-S1R** and **DC-S1** (June 2019), high-resolution cameras with full-frame sensors support 10-bit 4K HEVC video encoding [137][138]. **Panasonic AJ-CX4000**, an interchangeable-lens shoulder mount broadcast camera, supports HEVC recording up to 4K resolution with 10 bit and HLG HDR capability [139][140][141].
   37. **Sharp 8K UHD 30 fps micro four-thirds prosumer camera** (announced January 2019, further detail expected April 2019) [142].
   38. **JVC KA-EN200 streaming adapter** (September 2019) was introduced to enable HEVC in its GY-HC550 and GY-HC500 4K cameras [143]; and **KA-EN200G streaming adapter** (March 2020) with 10 bit 4:2:2 support in the JVC GY-HC900, GY-HC500 and GY-HC550 Connected Cam series camcorders [144].
   39. **Delta Digital 7840R military-grade rugged encoder** for airborne, ground-mobile, and shipboard environments, supporting HD and SD resolution (March 2020) [145].
   40. **Marshall Electronics** IP cameras CV730-BK, CV630-IP, CV420-30X-IP, and CV355-30X-IP for IP-based broadcast production workflows with HD and UHD video capabilities up to 60 fps, 8.5 MP sensors, 30× optical zom range, and triple video stream support (April 2020) [146].
   41. **Hardware chip support for televisions**: AMD, Broadcom, Huawei/HiSilicon (Hi series), Intel, Marvell (Armada series), MediaTek (MT series), MStar, Nvidia, RealTek (RTD series), Samsung, Sigma Designs (SX series), ViXS (XCode series).
   42. **Hardware chip support for mobile devices:** Qualcomm (Snapdragon series), MediaTek (MT, P, and Helio series), Intel (Z series), Samsung (Exynos series), Huawei (Kirin series), Xiaomi (Surge series).
   43. **Hardware chip support for security, surveillance, and Smart Home connectivity**: by Ambarella with 4Kp30 encoding and multi-stream support (January 2019) [147], by HiSilicon with 8Kp120 playback capability and some encoding capability (September 2019) [148], and by OmniVision with 4K and HDR encoding capability (January 2019) [149].
   44. **Professional encoding**: Ambarella, Ateme, AWS Elemental, Beamr, Cisco, Ericsson, Fraunhofer HHI, Harmonic, LiveU, NTT Electronics, Rohde & Schwarz, Socionext, and Vitec.
2. **4K UHD**: HEVC is the key enabler of the roll-out of 4K UHD television:
   1. **“It is the key that will unlock UHDTV broadcasting”**, said **DVB Steering Board Chairman Phil Laven** (5 June 2015) [150].
   2. **“You will not have 4K to the home without HEVC. Period.”** said **Matthew Goldman** (November 22, 2016), **President of SMPTE** and **SVP of Ericsson** [151].
   3. **Essentially *all* 4K televisions** have included HEVC support since 2014 or 2015. The number of such televisions passed 20 million in 2016 [8].
   4. Market penetration of 4K televisions reached approximately 10% in China by 2015 [26] and in France, Germany, Italy, Poland, Sweden, UK, and the U.S. by 2017 (per Huawei presentation at NAB 2017). Cisco systems reported in 2019 that “by 2022, nearly two-thirds (62 percent) of the installed flat-panel TV sets will be UHD, up from 23 percent in 2017” and that “UHD (or 4K) video will account for 22 percent of global IP Video traffic by 2022.” and “UHD as a percentage of IP VoD traffic will be higher at 35 percent by 2022” [6].
   5. **Ultra HD Blu-ray Disc** players support HEVC (exclusively) for UHD video (announced in September 2014, **BD ROM V3** specification July 2015) and the discs can also use HEVC for HD video. About 140 titles have been produced, and about 3 million discs have been sold (for roughly US$80 million). Multiple authoring solutions for UHD Blu-ray Discs are available.
   6. **Ultra HD Forum** “UHD Phase A Content Parameters” (initial release 1.1 released to the public July 2016, latest release 1.3 April 2017) specify 10-bit HEVC (exclusively) up to 60 fps.
3. **8K UHD**: HEVC has been used in deployments of 8K UHD television:
   1. The first broadcast channel via satellite for 8K UHD television, by NHK in Japan via B-SAT, uses HEVC [54][56].
   2. The live transmission of 8K from Rome to Tokyo for 8K UHD television, by NHK in Japan in partnership with Eutelsat, uses HEVC [55].
   3. 8K over broadband IP, via the **t-broad** service in Korea [64].
   4. Major display manufacturers, including Samsung, other members of the 8K Association [10][11], and LG Electronics [12], have included HEVC support in their 8K televisions, starting around early 2020.
4. **HDR**: HEVC has been a key element of the roll-out of **high dynamic range** video (**HDR**). HDR video provides a major improvement in the picture quality and sense of realism for HD and higher resolution, and most HDR video deployments have been based on HEVC:
   1. The most commonly implemented version of HDR is the so-called “HDR10” approach. At its core, HDR10 uses the HEVC Main10 profile (for 10 bit encoding of sample data). Two basic variants of HDR color representation have been deployed, one known as “perceptual quantization” (PQ) and the other known as “hybrid log-gamma” (HLG). While HDR10 is typically defined as using the PQ scheme, the HLG scheme is essentially the same in terms of how the video data is compressed and conveyed – i.e., using the HEVC Main 10 profile, and several important deployments have used the HLG variant (especially in Japan and the UK). The two variants are sometimes described as PQ10 and HLG10. Most HDR televisions support display of both the PQ and HLG for color representation together with supporting the HEVC Main 10 profile for the compression encoding.
   2. **BD ROM V3 for Blu-ray Discs** supports HDR video using HEVC.
   3. **Dolby Vision** HDR technology provides an enhancement of HDR10 using HEVC in either a single or dual layer system. A two-layer Dolby Vision HDR scheme is an optional format in BD ROM V3 for Blu-ray Discs. A different dual layer modality is used for OTT services with an SDR backward compatible mode. As of May 2017, approximately 150 movie titles and hundreds of hours of episodic television have been mastered and delivered in Dolby Vision using HEVC as the core compression standard [per personal communication].
   4. **Philips HDR** backward-compatible technology is also an enhancement of HDR10, consisting of HEVC video with display adaptation metadata for HDR-to-SDR down-conversion, and is another optional format in BD-ROM V3 for Blu-ray Discs.
5. **10-bit video**: HEVC has been a key enabler for the transition from 8-bit video to **10-bit video**, providing an improvement in color fidelity and a reduction in contouring effects:
   1. **Nearly all new televisions** (esp. 4K televisions) now include 10 bit HEVC support.
   2. **BD ROM V3 for Blu-ray Discs** supports 10 bit HEVC, but only 8 bit AVC.
   3. **Microsoft**’s **Xbox One** has supported 10 bit HEVC since June 5, 2015.
   4. **Ultra HD Forum** “UHD Phase A Content Parameters” (initial release 1.1 released to the public July 2016, latest release 1.3 April 2017) specify 10-bit HEVC (exclusively) up to 60 fps.
6. **High frame rate**: HEVC is also instrumental in enabling **high frame rate** (**HFR**) services:
   1. **BD ROM V3 for Blu-ray Discs** supports up to 60 fps with up to 4K resolution for HEVC, but only up to 24 fps with HD resolution for AVC.
   2. **ATSC 3.0** supports up to 120 fps with HEVC, and uses HEVC exclusively.
   3. **ARIB specifications for ISDB-S3** (STD-B32 and STD-B62) support up to 120 fps with HEVC with temporal sub-layer coding.
   4. **Ultra HD Forum** “UHD Phase A Content Parameters” (initial release 1.1 released to the public July 2016, latest release 1.3 April 2017) specify 10-bit HEVC (exclusively) up to 60 fps.
   5. **DVB**’s UHD Phase 1 specifies up to 60 fps with HEVC and its UHD Phase 2 specifies up to 120 fps with HEVC (exclusively) [152].
7. **Most video editing software packages**: HEVC is generally supported as an import and export format in most video editing software packages as of December 2018 [153].
8. Publicly available software source code implementations of HEVC that seem potentially compatible with integration into commercial products include the following:
   1. **HEVC model (HM)** reference software and related packages known as the Scalable HEVC Model (**SHM**), HEVC-based Multiview and 3D Test Model (**HTM**), and Screen Content Model (**SCM**) have been developed and made available continuously by the JCT-VC and JCT-3V during the development of HEVC and are available with a BSD-style license. These packages are especially useful for demonstrating the functionality and capability of HEVC and its extensions, and are often used for testing purposes and as the starting basis of implementations [154].
   2. **x265**, an encoder software package first released by MultiCoreWare in July 2013 and available under two alternative licensing programs (either GPLv2 or a commercial license). This software is widely used for speed-optimized encoding, and is used in a substantial number of other products and open-source packages [155].
   3. **Turing codec**, a software package released as a BBC open source project in September 2016, which was claimed to provide better coding efficiency than x265 [156][157]. Like x265, it is available either with a GPLv2 license or a commercial license.
   4. **SVT-HEVC**, an encoder software package released by Intel in October 2018 with a BSD-style license with an explicit patent grant for Intel patents [158][159]. It features optimized support for Intel Xeon processors, with modes for subjective and objective quality optimization and very-high-speed real-time encoding capability.
9. Publicly available software source code implementation of HEVC as an academic project:
   1. **Kvazaar**, an encoder software package developed by the Tampere University of Technology, in C with assembly optimization, available under a LGPLv2.1 license [160]. This project won an ACM Multimedia Open Source Software Competition Award in 2016 [161].

**Formal specifications with HEVC support**

Relevant formal specifications and their characteristics:

1. **3GPP specifications:**
   1. [**3GPP TS 26.234**](http://www.3gpp.org/DynaReport/26234.htm)**: Transparent end-to-end Packet-switched Streaming Service (PSS); Protocols and codecs** (all versions since version 12.3.0 published in March 2014, section 7.4) supports HEVC Main Profile Main Tier Level 3.1.
   2. [**3GPP TS 26.247**](http://www.3gpp.org/DynaReport/26247.htm)**: Transparent end-to-end Packet-switched Streaming Service (PSS); Progressive Download and Dynamic Adaptive Streaming over HTTP (3GP-DASH)** (all versions since version 12.2.0 published in March 2014, section 7.3.6) supports HEVC Main Profile Main Tier Level 3.1.
   3. [**3GPP TS 26.346**](http://www.3gpp.org/DynaReport/26346.htm)**: Multimedia Broadcast/Multicast Service (MBMS); Protocols and codecs** (all versions since version 12.1.0 published in March 2014, section 10.5) supports HEVC Main Profile Main Tier Level 3.1.
   4. [**3GPP TS 26.114**](http://www.3gpp.org/DynaReport/26114.htm)**: IP Multimedia Subsystem (IMS); Multimedia Telephony; Media handling and interaction** (all versions since version 12.5.0 published in March 2014, section 5.2.2) supports HEVC Main Profile Main Tier Level 3.1.
   5. [**3GPP TS 26.223**](http://www.3gpp.org/DynaReport/26223.htm)**: Telepresence using the IP Multimedia Subsystem (IMS); Media handling and interaction** (all versions since version 13.0.0 published in December 2015, section 5.2) supports HEVC Main Profile Main Tier Level 4.1.
   6. [**3GPP TS 26.140**](http://www.3gpp.org/DynaReport/26140.htm)**: Multimedia Messaging Service (MMS); Media formats and codecs** (all versions since version 12.0.0 published in March 2014, section 4.8) supports HEVC Main Profile Main Tier Level 3.1.
   7. [**3GPP TS 26.141**](http://www.3gpp.org/DynaReport/26141.htm)**: IP Multimedia System (IMS) Messaging and Presence; Media formats and codecs** (all versions since version 12.1.0 published in March 2014, section 5.3) supports HEVC Main Profile Main Tier Level 3.1.
   8. [**3GPP TS 26.116**](https://www.etsi.org/deliver/etsi_ts/126100_126199/126116/13.00.00_60/ts_126116v130000p.pdf)**: Universal Mobile Telecommunications System (UMTS); LTE; Television (TV) over 3GPP services; Video profiles** (version 13.0.0 published in May 2016, section 4.5) supports several HEVC operating points for 720p, 1080p, and UHD and usage with DASH delivery.
2. **8K Association** performance specifications for consumer TVs, announced in August 2019, require support of HEVC up to 60 frames per second with HDR support [10][11].
3. **ANSI/SCTE specifications:**
   1. **ANSI/SCTE 215-1 2015, HEVC Video Constraints for Cable Television Part 1 – Coding**, includes support of Main and Main 10 profiles and provisions for operation up to UHD (with HDR support) and HFR up to 60 fps for UHD and 120 fps for HD
   2. **ANSI/SCTE 215-2 2015, HEVC Video Constraints for Cable Television Part 2 – Transport**
   3. **SCTE 172 2017, Constraints on AVC and HEVC Structured Video Coding for Digital Program Insertion**
4. **ARIB specifications:**
   1. **ARIB STD-B32** “[Video Coding, Audio Coding, and Multiplexing Specifications for Digital Broadcasting](http://www.arib.or.jp/english/html/overview/doc/6-STD-B32v3_11-1p3-E1.pdf)” (Fascicle 1; latest release 3.11 July 26, 2018) includes support for HEVC up to 4K and 8K up to 120 fps with scalability for 60 fps (demonstrated with a real-time encoder developed by NHK in 2018) [162].
   2. **ARIB STD-B62** “[Multimedia Coding Specification for Digital Broadcasting (Second Generation)](http://www.arib.or.jp/english/html/overview/sb_ej.html)” (Fascicle 1, initial release 1.0 July 31, 2014; latest release 1.8 January 22, 2018) includes support for HEVC.
5. **ATSC 3.0:**
   1. [**ATSC A/300**](https://www.atsc.org/wp-content/uploads/2017/10/A300-2017-ATSC-3-System-Standard-4.pdf) (finalized standard, 19 October 2017) specifies the ATSC 3.0 System, and specifically identifies *only* HEVC for video use.
   2. [**ATSC A/341**](http://atsc.org/wp-content/uploads/2017/05/A341-2017-Video-HEVC.pdf) (finalized standard, 19 May 2017) specifies howHEVC is used in ATSC 3.0. This includes support for HEVC with several extended features including 10-bit HDR support (using either the PQ10 or HLG10 color representation scheme), high frame rate (up to 120 Hz), scalability, and multiview.
6. **BD ROM Version 3.0 for Blu-ray Discs** (per [White Paper publication](http://www.blu-raydisc.com/assets/Downloadablefile/BD-ROM_Part3_V3.0_WhitePaper_150724.pdf), section 2.2.3.3, July 2015) supports primary video streams in HEVC Main 10 Profile Level 5.1 up to 100 Mbps, resolution HD or 4K, frame rates 24–60 Hz (and AVC High Profile Level 4.1 up to 40 Mbps, 24 Hz only). For HDR, it supports “HDR10” a.k.a. “PQ10” with optional use of Dolby Vision layered coding and Philips HDR metadata for backward-compatible display adaptation.
7. **CTA/CEA** core characteristics for “connected” Ultra 4K HDTVs, released June 24, 2014, require that the TV “Decodes IP-delivered video of 3840x2160 resolution that has been compressed using HEVC,” with a minimum capability of “Main Profile, Level 5, Main tier” [163].
8. **Digital UK**, [*Freeview Play – Technical Specification 2017 Profile, v2.1.1*](http://www.digitaluk.co.uk/fvp-spec) (September 8, 2016) specifies HEVC exclusively for HD and UHD with 10 bit support and UHD HDR with the HLG10 color representation scheme (otherwise generally similar to ETSI/EBU TS 102 796).
9. **ETSI/DVB Technical Specification 101 154:**
   1. v2.2.1 of June 2016 includes HEVC for HD (up to 60 fps, with 8 or 10 bit capability) and specifies HEVC exclusively for UHD Phase 1 (up to 60 fps, with 8 or 10 bit encoding but without HDR support)
   2. v2.3.1 of February 2017 (and Blue Book A57 of November 2016) specifies HEVC exclusively for UHD Phase 2, including up to 120 fps HFR and 10-bit HDR (using either the PQ10 or HLG10 color representation scheme)
10. **ETSI/EBU Technical Specification 102 796 (v1.4.1) Hybrid Broadcast Broadband Television (HbbTV) v2.0.1** (August 2016) includes HEVC streaming for HD and UHD with 8 or 10 bit formats (generally similar to ETSI/DVB TS 101 154).
11. **NATO and U.S. MISB military specifications:**
    1. **ST 1101 STANAG 4586 Control of Motion Imagery Payloads** (2014) includes HEVC approval with explicit codepoints for Main and Main 10 profiles and allowance for encoder-specific profile selections (with provisions for HD and UHD usage) [164][165]
12. **Ultra HD Forum** “[UHD Phase A Content Parameters](https://ultrahdforum.org/resources/phasea-guidelines-description/)” (initial release 1.1 released to the public July 2016, latest release 1.4 September 2017) specify 10-bit HEVC (exclusively) and include HDR support using either the PQ10 or HLG10 color representation scheme.

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