QuickTime and MPEG-4: Now Featuring H.264

The Benefits of Standards

Confidence. Quite simply, standards build confidence. Because of standards, you can be sure that any CD plays in any CD player; any television station can be viewed on any brand of television; any DVD plays in any DVD player.

Innovation and new markets. Instead of a world of small competing technology fiefdoms, standards create the foundation for widespread adoption of innovative new consumer products. Satellite television is based on the MPEG-2 standard developed in 1994. Standard audio formats have made MP3 players commonplace.

Economy. As standards are ratified, the industry can focus on how to deploy them at a lower cost instead of developing redundant technologies. The adoption of the MPEG-2 standard allowed the broadcast and DVD industries to focus their efforts on developing innovative tools for creating and delivering MPEG-2 rather than developing alternatives to MPEG-2, ultimately lowering delivery costs.

Choice. Standards enable the builders of media networks to select products from a number of vendors and integrate them into a single, scalable system. Competition between vendors results in a broader choice of products varying in cost, performance, and features.

Reduced costs. Using standards, content providers can eliminate the time-consuming and costly process of encoding and managing the same material in multiple formats.

Increased revenue. Content providers can leverage standards to offer their content via new platforms such as mobile networks, the Internet, and digital television.

The most exciting phase in the evolution of MPEG-4 is well under way. MPEG-4, the newest in a long line of successful worldwide multimedia standards, now includes H.264 video. Providing stunningly beautiful video in compact files, H.264 is revolutionizing virtually every application that uses video, from mobile multimedia to video conferencing to broadcast and satellite television.

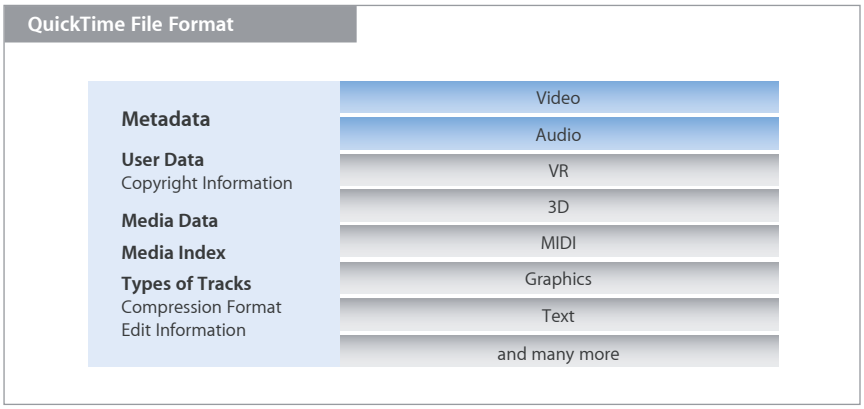
What Is MPEG-4?

MPEG-4 is a multimedia standard with audio and video at its core. It was defined by the MPEG (Moving Picture Experts Group) committee, the working group in the International Organization for Standardization (ISO) that specified the widely adopted, Emmy Award–winning standards known as MPEG-1 and MPEG-2. MPEG-4 is the result of an international effort involving hundreds of researchers and engineers. The initial parts of MPEG-4, whose formal designation is ISO/IEC 14496, were finalized in October 1998 and became an international standard in early 1999.

MPEG-4 was created to ensure seamless delivery of high-quality audio and video over the Internet, on IP-based networks, and to a new generation of consumer digital media devices. Because these devices range from narrowband cell phones to broadband set-top boxes to broadcast high-definition (HD) televisions, MPEG-4 provides high-quality audio and video across the entire bandwidth spectrum.

Based on a time-tested technology

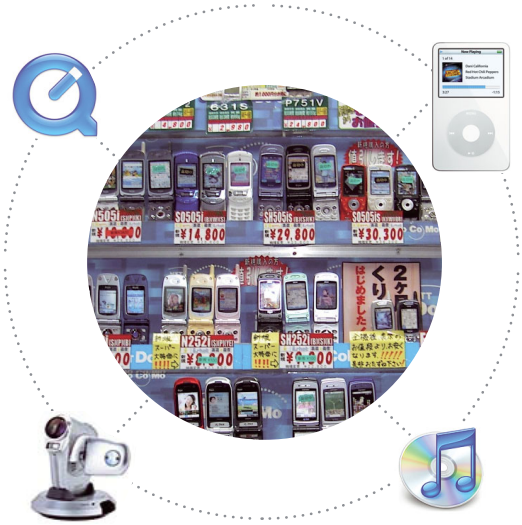
The ISO could have chosen to base its MPEG-4 standard on any existing file format, or it could have created an entirely new format. The ISO chose to use the QuickTime File Format because of its decade-long track record in the industry. Quite simply, QuickTime works. Designed from the ground up to be cross-platform and media agnostic while providing stability, extensibility, and scalability, QuickTime delivers the foundation needed to encode, process, and play digital media on any MPEG-4–compliant device. Since its inception in 1991, QuickTime has incorporated the best technology available to deliver the highest possible quality.



The QuickTime File Format is a "container" that can hold a variety of media types and their respective data, such as audio, video, animations, text, images, and VR. QuickTime packages these media types as "tracks," which are a key component of what has made QuickTime so adaptable. New capabilities can be added simply by creating new track types. What's more, new versions of QuickTime maintain backward compatibility, ensuring the continued viability of multimedia developed with earlier versions. This unique combination of flexibility and backward compatibility made the QuickTime File Format the perfect choice for the basis of MPEG-4.

MPEG-4 Success

MPEG-4 is an extremely well-adopted format. It has been distributed in QuickTime 6 to hundreds of millions of Internet users around the world. It has been built into digital video and still cameras from some of the industry's largest companies. It is the format used in the incredibly popular iPod and iTunes Music Store. And it has been built into tens of millions of multimedia-enabled cell phones around the world.



In addition to the flexible MPEG-4 file format, the technologies at the heart of this success to date are the MPEG-4 Part 2 video codec and the Advanced Audio Coding (AAC) audio codec.

MPEG-4 Part 2 video delivers improved compression efficiency over previous video standards by employing updated coding tools and techniques. For example, the codec provides single-pass variable bit rate (VBR) control, meaning that the encoder can be set to a target data rate that ensures playback at the appropriate rate for a particular delivery mechanism. In addition, the QuickTime MPEG-4 Part 2 codec features rigorous color management, a motion estimator optimized for both precision and speed, and a high-performance quantizer, all of which work together to provide high-quality video time after time. The decoder also provides an optimized post-processing stage to remove coding artifacts. The encoder and decoder are optimized for PowerPC- and Intel-based systems. Finally, the QuickTime MPEG-4 Part 2 codec is compatible with numerous other MPEG-4 technologies, as proven in a host of industrywide interoperability tests.

AAC audio provides much more efficient compression than older formats like MP3, yet it delivers quality rivaling that of uncompressed CD audio. AAC was developed by the MPEG group that includes Dolby, Fraunhofer (FhG), AT&T, Sony, and Nokia—the same audio experts that created MP3 and AC-3. Taking full advantage of the many advances in perceptual audio coding and compression achieved since the development of MP3 more than a decade ago, AAC delivers higher-quality output at lower data rates. And with support for modern audio requirements such as multichannel audio at up to 48 full-frequency channels and high-resolution sampling rates up to 96kHz, AAC proves itself worthy of replacing MP3 as the new standard for Internet audio. The AAC codec in QuickTime builds on state-of-the-art signal processing technology from Dolby Laboratories and offers both a constant bit rate mode for bandwidth-constrained scenarios and a constant quality mode for a consistently high-quality listening experience.

An evolving standard

The beauty of the MPEG standards is that they don't stand still. As evidenced by the long and continually improving life of MPEG-2, standard formats can and do evolve as technologies advance. MPEG-4 is no different. Over the last few years, hundreds of the world's finest video experts in hardware, software, video telephony, authoring, streaming, cable, television, and DVD have been hard at work specifying, scrutinizing, evaluating, verifying, and ratifying the next-generation standard for video. Working jointly with the International Telecommunications Union (ITU), the MPEG committee created ITU-T Recommendation H.264|ISO/IEC 14496-10 AVC, otherwise known as MPEG-4 Part 10 or, more simply, H.264.

H.264: A Revolution in Quality and Coding Efficiency

H.264 is an intricate web of the latest innovations in video compression technologies that together provide a vast improvement over previous generations of video codecs. For example, H.264 delivers the same quality as MPEG-2 at a third to half the data rate. When compared to MPEG-4 Part 2, H.264 provides up to four times the frame size at a given data rate.

Thanks to its impressive efficiency, H.264 provides up to four times the resolution of MPEG-4 Part 2 at the same quality and data rate.

In addition to exceptional efficiency, H.264 provides better image quality than past standards when reaching its limits. Rather than breaking down into distinct blocks and jagged objects, H.264 degrades gracefully, softening an image as compression increases.

It's important to keep in mind that H.264 is at the beginning of its life cycle; users can expect many years of improvement from this incredible foundation of compression technologies. Just as today's MPEG-2 video quality exceeds the highest expectations of more than a decade ago when the MPEG-2 standard was ratified, H.264 will improve with age.

Scalable from 3G to HD and beyond

With H.264, the ITU and MPEG groups set out to achieve the best-ever compression efficiency for a broad range of applications—from broadcast and DVD, where MPEG-2 is traditionally used, to video conferencing, which has used H.263, to video on demand, streaming, and multimedia messaging, which have used MPEG-4 Part 2. Their efforts were successful: H.264 delivers excellent quality across a wide operating range, from 3G to HD and everything in between. Whether creating video for mobile phones, iChat AV, the Internet, broadcast, or satellite delivery, H.264 provides exceptional video quality at impressively low data rates.

H.264: Exceptional quality at any size

Scenario/Use	Resolution and frame rate	Example data rates
Mobile content (3G)	176 by 144, 10–24 fps	50–160 Kbps
Internet/Standard definition (SD)	640 by 480, 24 fps	1–2 Mbps
High definition (HD)	1280 by 720, 24p	5–6 Mbps
Full high definition (full HD)	1920 by 1080, 24p	7–8 Mbps

The impressive efficiency of H.264 makes state-of-the-art video more accessible to more people, enabling anyone to experience the full quality of HD video on today's computers. With H.264, HD video plays back seamlessly on all current Macintosh systems.

The Benefits of H.264

Unprecedented video quality. H.264 uses the latest innovations in video compression technology to provide consistently crisp and clear video for the best possible viewing experience.

Ultra-efficient. H.264 delivers incredible video quality at data rates one-fourth to one-half the size of previous video formats.

Scalable from 3G to HD. Use a single codec for all your delivery needs. H.264 delivers great results for everything from mobile multimedia to Internet to satellite and beyond.

HD playback on today's computers. High-definition H.264 video plays back seamlessly on today's Mac hardware. With an Apple Cinema HD Display and a Mac Pro, the home office is now the home theater.

Ratified standard for industrywide interoperability. H.264 content created with QuickTime can play back on a broad range of H.264 devices, including mobile phones, iPods, set-top boxes, DVD players, and more. Likewise, files created with these devices can play back in QuickTime.

H.264 plays on today's computers.

Features of the H.264 standard

The H.264 standard fully specifies the H.264 bit stream and decoder, while more generally specifying a set of encoding tools that can be used in creating H.264 content. The H.264 encoding toolset incorporates the best ideas from past video standards, improves on them, and adds many more new technologies. The list of tools and technologies is quite extensive; here are a few of the most notable.

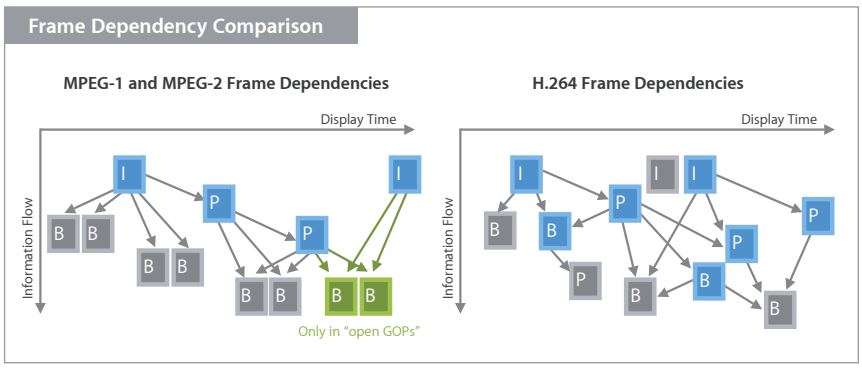
Advanced Design

H.264 uses a richer set of techniques, in a more orthogonal fashion, than previous standards like MPEG-2 to increase coding efficiency. In previous coding techniques, singly predicted (P) frames depended only on previous independently coded (I) or P frames, and bipredicted (B) frames depended on a past and a future I or P frame.

In H.264, different parts of a picture may use different types of coding (I, P, or B), and the parts using P or B coding may depend on different frames. In addition, H.264 involves four separate concepts: the direction of prediction, the number of dependencies (one or two), the coding style of the material that is depended on (I, P, or B), and which prior or subsequent frame or block contains the reference. I material has no dependency; P material has a single dependency, which may be of any kind and in the past or the future; and B material has two dependencies, which also may be of any kind and in the past or the future. Material that depends on a future frame requires that the frame be decoded before it but displayed after it—called frame reordering. In previous standards, frame reordering was only possible when using B-frames; however, with H.264, it can occur for any type of prediction (B or P).

The H.264 decoder maintains a set of decoded reference frames, any of which may be depended on by the material that is to be decoded. No longer is the dependency limited to the previous and next I or P frame.

Given the choices available to the encoder and other improvements in coding, H.264 delivers a truer representation of the source material in a much lower data rate than other codecs.



4x4 integer transform. H.264 is designed to operate on much smaller blocks of pixels than other common codecs, which mitigates blocking, smearing, and ringing artifacts. So H.264 video is crystal clear even in areas of fine detail. Because the transform is a precisely specified integer transform, it provides bit-precise reconstruction (that is, exact-match decoding) rather than statistically generated reconstruction. As a result, there can be no drift among various decoder implementations, so any compliant H.264 decoder will decode the video exactly as the content author intended it to look.

Increased precision in motion estimation. H.264 also benefits from increased precision in motion estimation, which is the process of simplifying redundant data across a series of frames. By expressing information to 1/4-pixel resolution as opposed to 1/2-pixel resolution like most other codecs, H.264 represents both fast- and slow-moving scenes more precisely. So objects in motion are more crisply reconstructed during decode, providing a better representation of the source material.

Flexible block sizes in motion estimation. During motion estimation, traditional codecs commonly process frames at the macroblock level (16 pixels by 16 pixels). H.264 can process on segments within a macroblock, ranging in size from the commonly used 16x16 to as small as 4x4, which helps to code complex motion in areas of high detail. The ability of H.264 to perform its processing on a variety of block sizes means that scenes with complicated motion are more expressively described, providing higher quality in lower data rates.

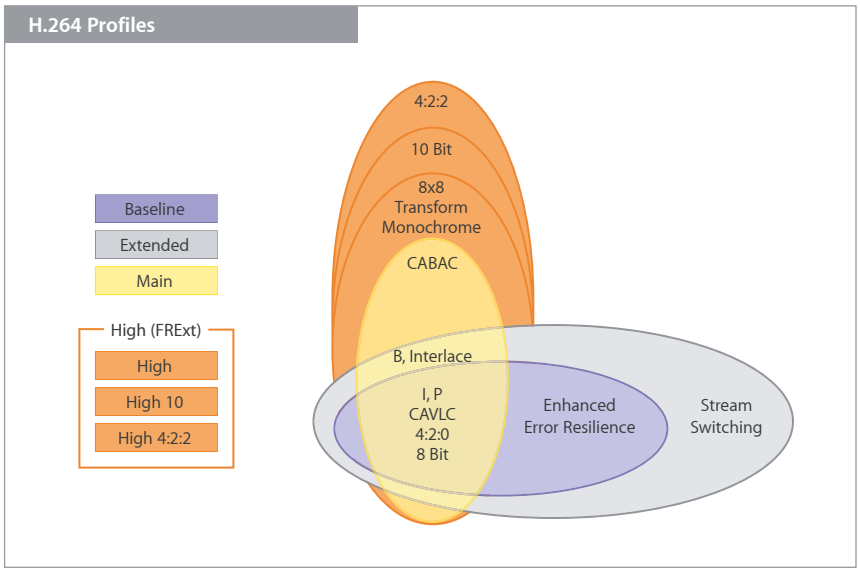
Intraframe prediction. H.264 is able to gain much of its efficiency by simplifying redundant data not only across a series of frames, but also within a single frame, a technique called intraframe prediction. The H.264 encoder uses intraframe prediction with more ways to reference neighboring pixels, so it compresses details and gradients better than previous codecs. Intraframe prediction is especially beneficial in high-motion areas, which are traditionally difficult to encode. With H.264, high-motion video can achieve stunning quality at much lower data rates.

Adaptively tuned deblocking filter. H.264 also features a robust deblocking filter, which operates on 4x4 block boundaries to remove jagged blocking artifacts. Its filtering is adaptively tuned per block boundary, making it a very effective smoothing filter during the decoding of a finished bit stream. In addition to making smoother pictures for display, this filter is used during the encoding process to provide a more coherent reference picture for subsequent frames, which helps to improve image quality. This advanced filter technology effectively eliminates blocking artifacts, resulting in a smooth, clean picture.

Profiles and levels

Like any comprehensive standard, the H.264 standard defines a set of profiles and levels to set points of conformance for various classes of applications and services. In each profile, specific encoding tools are permitted to best meet the needs of the intended scenario. H.264 includes six profiles:

- **Baseline.** Intended for low-complexity applications such as video conferencing and mobile multimedia.
- **Main.** Intended for the majority of general uses, such as the Internet, mobile multimedia, and stored content.
- **Extended.** Intended for streaming applications, where stream switching technologies can be beneficial.
- **Three High profiles** (also known as Fidelity Range Extension or FREXt). Consists of three separate High profiles (High, High 10, and High 4:2:2), intended for high-end professional uses.



For each profile, 16 levels can be applied, each specifying a typical frame size, frame rate, and maximum data rate. The same 16 levels are used for each profile. The extensive system of levels was designed to provide flexibility while at the same time constraining the decoder complexity and bandwidth used. A level limits complexity and bit-rate, and though each level has a typical use-case (see table below), many other patterns of frame rate and frame size are possible within each level.

H.264 levels

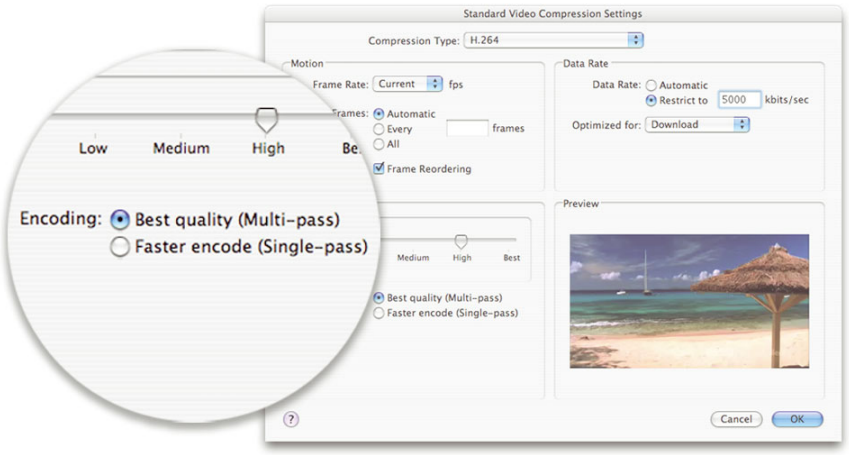
Level	Typical picture size	Typical frame rate	Maximum bit rate (non-FREXt)
1	QCIF	15	64 Kbps
1b	QCIF	15	128 Kbps
1.1	CIF or QCIF	7.5 (CIF)/30 (QCIF)	192 Kbps
1.2	CIF	15	384 Kbps
1.3	CIF	30	768 Kbps
2	CIF	30	2 Mbps
2.1	HHR (480i or 576i)	30/25	4 Mbps
2.2	SD	15	4 Mbps
3	SD	30/25	10 Mbps
3.1	1280x720	30	14 Mbps
3.2	1280x720	60	20 Mbps
4	HD 1080	30	20 Mbps
4.1	HD 1080	30	50 Mbps
4.2	1920x1080	60	50 Mbps
5	2048x1024/16VGA	72/30	135 Mbps
5.1	4096x2048	30	240 Mbps

Apple's H.264 Video Codec: Under the Hood

The H.264 standard specifies the decoder and bit stream syntax, but leaves the methodology of encoding up to the individual implementation. Leveraging its many years of experience in creating successful video coding technologies, Apple has created an industry-leading H.264 implementation in QuickTime 7. Using a combination of specified technologies and patent-pending techniques, the QuickTime H.264 video codec produces phenomenal results.

Intelligent multipass encoding

Apple's implementation of the H.264 encoder employs a patent-pending technology for using the optimal number of passes to produce the best possible quality at the desired bit rate. This technology produces superior quality and bit rate efficiency compared with traditional dual-pass and single-pass encoders, and it takes the guesswork out of the encoding process by intelligently determining the optimal number of compression passes to perform.



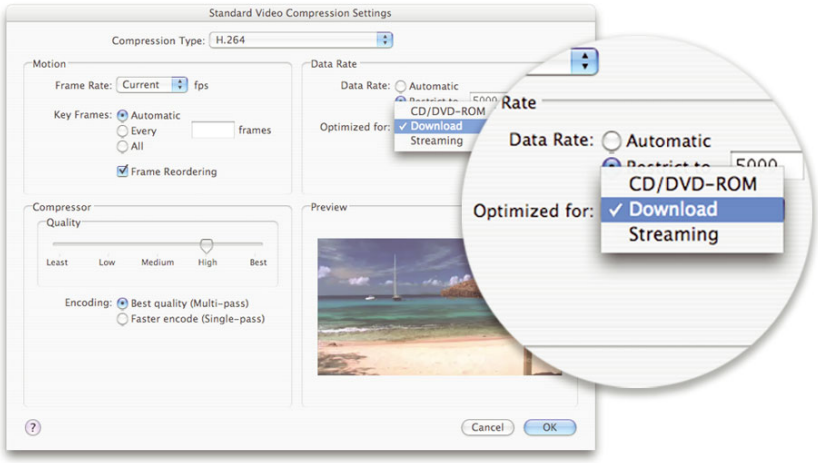
H.264 encoding modes in QuickTime 7 Pro.

Single-pass encoding mode

When encoding speed is a higher priority than pristine quality, the QuickTime 7 H.264 encoder offers a single-pass encoding mode for a good result in a very short time. Using patent-pending techniques, this accelerated encoding mode saves time when the user wants to create "draft" versions of an encode or when a deadline is quickly approaching.

Peak-constrained VBR options

QuickTime 7 allows the user to limit the upper boundary of the H.264 variable bit rate encode for bit rate–constrained situations. The H.264 encoder offers peak-constraining options tailored to two specific playback scenarios: streaming and CD-ROM/DVD. Apple's patent-pending technology for constraining peak data rate delivers better visual quality for a given bit rate and ensures a smooth playback experience for narrowband connections and devices such as CD-ROM and DVD players.



Peak-constrained VBR options for H.264 in QuickTime 7 Pro.

Conformance

The initial implementation of Apple's H.264 decoder conforms to all levels of Main profile in progressive format. Apple's H.264 encoder can create MPEG-4 files that interoperate with both Baseline and Main profile-conforming decoders.

Innovating to deliver exceptional quality

Because the set of encoding tools in the H.264 standard is specified but not explicitly defined, Apple is able to create a superior H.264 video encoder using newly invented techniques. The QuickTime H.264 encoder benefits from patent-pending technologies in the areas of intelligent multipass encoding, single-pass encoding, constraining peak data rate, bit allocation, and motion estimation to deliver unparalleled quality.

H.264 Throughout the Apple Product Line

Apple has a long history of using standards to support the adoption of innovative technologies, and MPEG-4 is no exception. From USB and Bluetooth connections for peripherals, to AirPort (802.11) wireless networking, to FireWire (IEEE 1394) high-speed digital video transfer, Apple has championed technology standards that have been adopted throughout the industry. Apple has worked closely with the MPEG committee to define and ratify the MPEG-4 standard, including the latest addition to the standard, H.264. Having spent years contributing to and then implementing the H.264 standard, Apple is now ready to introduce this outstanding technology throughout its product line.

As the foundation on which other multimedia applications at Apple are built, QuickTime houses H.264 as well as a multitude of other popular video, audio, and still image codecs. Because H.264 is built into the QuickTime architecture, QuickTime-based applications can take full advantage of this new video codec.

QuickTime is an essential component of the Mac OS X operating system. The latest version of Mac OS X, v10.4 "Tiger," leverages the H.264 support in QuickTime 7 to deliver high-quality, multiperson video chatting in iChat AV, as well as to display H.264 video in the Finder, Preview, Safari, and Mail.

QuickTime 7 also brings the benefits of H.264 to Apple's consumer applications. Users can enjoy stunning H.264 video playback in QuickTime Player and iTunes. They can create high-quality H.264 versions of their iMovie projects for sharing with others via email or the web. And users can create impressive presentations by incorporating beautiful H.264 video in Keynote projects.

For video professionals, H.264 brings even more exciting possibilities. Thanks to the H.264 support in QuickTime 7, Final Cut Studio users have the ability to deliver high-quality content at lower data rates for the web and DVD. Final Cut Studio includes Compressor, which allows users to tap the power of networked Macintosh computers to dramatically reduce H.264 encoding times. When Compressor is coupled with Xsan, the SAN file system for Mac OS X, encoding from uncompressed high-definition video to H.264 is dramatically accelerated. DVD Studio Pro 4 leverages the quality and efficiency of H.264 to deliver HD quality at SD data rates on DVD. DVD Studio Pro 4 is the first commercially available DVD authoring software that lets users burn their HD projects to high-definition DVDs based on the latest HD DVD specifications. Created using existing DVD burners and media, these discs can play back high-definition content in H.264 on any of the latest Macintosh hardware with the latest version of Apple's DVD Player, which also leverages H.264 support in QuickTime 7.

Widespread Industry Adoption of H.264

Apple is not the only company embracing H.264. Many standards organizations and hundreds of companies are actively working to incorporate this new video standard into their specifications and products. Standards bodies and industry consortia supporting H.264 include the following.

Moving Picture Experts Group (MPEG). As mentioned earlier, H.264 has already been ratified by the MPEG committee as part of the MPEG-4 standard, specifically called MPEG-4 Part 10 or Advanced Video Coding (AVC).

International Telecommunication Union (ITU). The cocreator of H.264, ITU, has ratified H.264 as its next video conferencing standard.

DVD Forum. H.264 has been selected by the DVD Forum as mandatory for its HD DVD specification, which defines one of two formats for next-generation, high-definition DVDs.

Blu-ray Disc Association. H.264 has also been chosen by the Blu-ray Disc Association as mandatory for its Blu-ray Disc specification, which defines the other of the two formats for next-generation, high-definition DVDs.

Digital Video Broadcasting (DVB). This European-born consortium for creating digital television standards has chosen H.264 as part of its specification for broadcast of both SDTV and HDTV.

T-DMB. Terrestrial Digital Multimedia Broadcasting is an ETSI standard specified to include H.264 for video. T-DMB has been adopted in South Korea and Germany. Many other European countries are currently in trials.

3rd Generation Partnership Project (3GPP). This group creates standards for mobile multimedia on GSM-type mobile networks. It has chosen H.264 as the primary video codec in its Release 6 specification.

Internet Streaming Media Alliance (ISMA). H.264 has been adopted by the ISMA, which was formed to accelerate the adoption and deployment of open standards for streaming rich media content over Internet protocols.

MPEG Industry Forum (MPEGIF). This group was created to further the adoption of MPEG standards, including H.264, through promotion, interoperability testing, certification programs, and other activities.

AVC Alliance. Formed to promote H.264 (sometimes called AVC) based products and services that work together seamlessly, the AVC Alliance is made up of some of the industry's leading international companies.

H.264 is also under consideration for adoption by other standards groups, including the 3rd Generation Partnership Project 2 (3GPP2), the group creating standards for mobile multimedia on CDMA2000 networks; and Advanced Television Systems Committee (ATSC), the U.S. group creating standards for digital television.

In addition to its broad standards support, numerous broadcast, cable, video conferencing, and consumer electronics companies consider H.264 the video codec of choice for their new products and services. Some of the most notable are Japan's top six broadcasting companies, DirecTV, Tandberg, and Philips.

MPEG-4, H.264, and QuickTime 7

The already successful MPEG-4 standard now features H.264, a video codec that delivers unparalleled quality with even more impressive efficiency. Using the latest innovations in video compression technology, H.264 delivers incredible results for the entire range of applications, from mobile to Internet to satellite and beyond. Now that H.264 is built into the QuickTime 7 architecture, QuickTime-based applications from Apple and other companies can offer H.264 encoding and decoding capabilities. Best of all, H.264 is a broadly supported standard. This adoption by a wide variety of open standards means that any company in the world can create devices—mobile phones, set-top boxes, DVD players, and more—that interoperate with QuickTime 7.

Get ready for QuickTime 7 with H.264 to change the digital video universe. Experience this powerful addition to QuickTime 7 today.

For More Information

For more information about QuickTime products and MPEG-4 technologies, visit www.apple.com/quicktime.

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