SOLUTIONS PAPER

MPEG-4 Network Migration: Solutions and Benefits

Introduction

MPEG-4 is a standard for video compression that allows network operators to dramatically improve digital video bandwidth utilization by roughly twice the comparable MPEG-2 industry benchmark for digital video distribution. Telcos, cable operators, and satellite service providers can benefit from the resulting bandwidth efficiencies, and there is a growing trend toward increasing use of MPEG-4 services on digital networks. As digital network operators migrate to MPEG-4 services, there are economic and interoperability issues to address so that service providers can efficiently leverage existing MPEG-2 infrastructure assets while progressively integrating MPEG-4 services deeper into their networks.

Network operators clearly want to optimize the value of their established MPEG-2 set-top and infrastructure investments, so developing and implementing a cost-effective migration to MPEG-4 requires a careful balance of mixed-mode operation where core, regional, and access networks enable the co-existence of MPEG-2 and MPEG-4 services. This paper reviews the market drivers leading service providers to increasingly migrate to MPEG-4 services, compares and contrasts MPEG-2 and MPEG-4 technologies, discusses related interoperability challenges, and highlights end-to-end solutions from Motorola that allow operators to implement MPEG-4 video services in their networks.

The Need for Greater Compression

Consumer demand for a wide range of high-quality video content is increasing, and service providers are under added pressure to keep up with competitive offerings. Increasing High Definition (HD) content, Video On Demand (VOD) alternatives, and a greater range of custom programming is putting a strain on existing network infrastructures. Bandwidth is increasingly precious, and the ability to make the most efficient use of bandwidth will drive the long-term success of network operators. Increased deployment of MPEG-4 services is a real and near-term tool for operators to maximize bandwidth utilization in their networks and, in turn, to deliver an increasing amount of high-quality video content to their subscribers.

Introduced in late 1998, MPEG-4 is a standard used primarily to compress digital audio and video so that it can be efficiently transmitted through the network for distribution and delivery to the end subscriber. The MPEG-4 standard yields excellent video quality at roughly 50% of the bitrate of its MPEG-2 predecessor, as currently implemented.

Today, MPEG-2 is the most widely deployed and most common scheme for digital video compression for Hybrid Fiber Coax (HFC) networks. For efficient distribution, the majority of content providers digitize and compress their video feeds using MPEG-2 and/or MPEG-4 encoders and transmit them to network operators via satellite. The compressed content is then transported across core, regional, and access networks until it is delivered to the set-tops in the home. Most of the currently deployed set-tops today are designed with MPEG-2 decoders. A single HD channel typically transports at 15 to 19.3 Mbps using MPEG-2, but can transport at 8 to 10 Mbps using MPEG-4. MPEG-4 compression effectively squeezes video traffic into a smaller "pipe"—opening up extra billable capacity that service providers can leverage to promote extended content and services that drive revenue growth and customer satisfaction.

Historically, Telcos have been early adopters of MPEG-4 migration, primarily because of the video bandwidth constraints on DSL access networks and their emergence into video services with the latest IPTV technologies. But MSOs and satellite providers are also building out MPEG-4 infrastructures so they can deliver the broadest range of video content possible to remain competitive, capture and retain subscribers, and reduce churn. MPEG-4 was initially used for satellite transmission, since satellite bandwidth is typically the most expensive and most constrained point of the network. MPEG-4 migration is now expanding throughout the entire video delivery network, from the satellite downlink through the central office or headend and to the home, as HD and VOD demand growth is pushing the need for increased network transmission efficiencies.

The need for efficient bandwidth utilization is increasing, and MPEG-4 migration strategies are a significant component of an overall bandwidth optimization strategy. The ability to enable the seamless coexistence of MPEG-2 and MPEG-4 services within the network is essential so that service providers can drive MPEG-4 further into the network while continuing to monetize existing infrastructure and continuing to support the tens-of-millions of MPEG-2 set-tops already deployed worldwide.

Newer set-tops utilizing MPEG-4 Advanced Video Compression (AVC) are capable of decoding both MPEG-2 and MPEG-4 compressed digital streams, otherwise known as "dual format". These set-tops can be installed into an MPEG-2 network and offer future proofing as the transition to MPEG-4 is eventually extended to the home.

An Overview of the MPEG Standards

MPEG-2 is widely used today as the format for digital television transmission by terrestrial (over-the-air), cable, Fiber To The Premise (FTTP), and direct broadcast satellite TV systems. It is also the prevalent format of movies and other programs that are distributed on Standard Definition (SD) DVD video discs. As HD becomes more prevalent, MPEG-4 AVC has become the chosen profile used on Blu-ray and HD DVD discs.

Development of MPEG-4 started shortly after the MPEG-2 standard was published. By 1999, MPEG-4 was yielding an immediate 20% improvement compared to MPEG-2. Four years later, and with increased refinement, MPEG-4 was given ISO status (ISO 14496) and side-by-side comparison tests routinely showed improvements of 50% or higher. These significant gains in coding efficiency are due to the development of numerous new standardized coding tools that can be applied as needed to the compression goals set by encoder manufacturers. The new tools provide major opportunities for content providers, service providers, and users because MPEG-4:

- Allows a video picture to be subdivided into macroblock regions that can be shaped to adapt to the areas of varying detail within the picture.
- Has standardized a de-blocking filter that causes complex areas of the picture to have smoothed edges rather than the sharp, blocky-type artifacts that MPEG-2 yields when there is not enough bandwidth to adequately compress the picture.

While MPEG-4 introduces a large number of new tools, two that provide a significant departure from MPEG-2 techniques and provide a major portion of the coding gains are variable sized macroblocks and multiple reference frames.

MPEG Compression Formats

MPEG-1 was the initial video and audio compression standard. It is used as the standard for video CDs, and it includes the MP3 audio compression format.

MPEG-2 establishes transport, video, and audio standards for broadcast-quality television. It is widely used for over-the-air and digital satellite TV services, and service providers worldwide rely on MPEG-2 today to centrally compress video files for distribution across transport networks to the home.

MPEG-3 was originally designed for HD TV, but abandoned when it was realized that MPEG-2 with extensions was sufficient.

MPEG-4 absorbs many of the features of the MPEG-1 and MPEG-2 standards to support video/audio objects, and it adds a comprehensive set of new video analysis and compression tools to accomplish more efficient coding than possible with previous MPEG standards. Today, MPEG-4 Part 10 AVC (H.264) is the common profile and displaces MPEG-4 Part 2 Simple Profile (SP) and Advanced Simple Profile (ASP).

Variable-Sized Macroblocks

MPEG-4 enables the coding of individual objects. This means that the video information needs not be of a rectangular shape, as MPEG-1 and MPEG-2 video assume. In MPEG-2, macroblocks are fixed at 16x16 pixels, so that picture representations can only be broken down as fine as a single macroblock. With MPEG-4, encoding algorithms can apply a variety of sub-macroblock sizes (from 4x4 to 16x16, with rectangular and square regions as options) so that each sub-macroblock can be selected to efficiently enclose an area of the picture that contains varying levels of detail or motion. Areas with a greater degree of detail are assigned smaller macroblocks than the broader, homogeneous areas, allowing enhanced compression.

Multiple Reference Frames

Motion vectors—which track the movement of macroblocks between frames—can be applied to the sub-macroblocks and more accurately track the motion of picture elements. For motion estimation, MPEG-2 uses three frame types and dictates strict relationships between these frame types.

- "I" frames are standalone frames and completely represent one frame of video.
- "P" frames are unidirectional predicting frames, which contain information used to "predict" the movement of macroblocks compared to an I frame.
- "B" frames are bi-directional frames that predict the location of macroblocks either before or after the current P frame.

Under this scheme, only two frames are ever considered when building or decoding the current frame. MPEG-4 has introduced the concept of multiple reference frames, where any frame can reference the data in any other frame, within a five-frame sequence. For example, consider the scenario where an object (macroblock) that is visible in the first frame moves behind another object in the third frame and reappears in the fifth frame. Using MPEG-2 techniques, the macroblock would have to be duplicated in frame #5 since reference frames before and after contain no valuable information. With MPEG-4, the data in the first frame can be referenced in the fifth frame, thereby avoiding the duplication of the object data. This enables enhanced compression today and also potentially enables new applications in the future that track objects on-screen.

Transitioning to MPEG-4

Managing the transition to MPEG-4 is a challenge for service providers currently deploying MPEG-2 content because they must concurrently manage both MPEG-4 and MPEG-2 compressed video streams within their networks. In this situation mixed-mode (dual format) transmission is inevitable, as network operators increasingly process MPEG-4 content and deliver it further into the network while continuing to support legacy MPEG-2 equipment.

Service providers need flexible options for managing mixed-mode transmission as they migrate from MPEG-2 to MPEG-4. Total, end-to-end MPEG-4 video delivery is the desired end-game; the compression advantages are clear. However, the path to MPEG-4 delivery from the core network to the home requires careful planning and the correct selection of the optimum network and access products. Choosing the right vendor is essential for managing the transition to MPEG-4, and Motorola offers the end-to-end solutions that allow carriers, satellite network operators, and cable operators to migrate to MPEG-4 at the pace that makes most economic sense for their business.

Managing Mixed-Mode MPEG-2 and MPEG-4 Transport

Motorola offers the products and professional services expertise to help service providers navigate the complexities of MPEG-4 AVC migration, and provides flexible options for enabling the co-existence of mixed-mode MPEG-2 and MPEG-4 AVC traffic. Service providers can manage capital costs for the further buildout of MPEG-2 infrastructure while gradually building out incremental MPEG-4 delivery capabilities. They can convert MPEG-4 to MPEG-2 at satellite downlink locations on the core network, or carry MPEG-4 traffic deeper into the network and convert it at regional networks. The further that a service provider can transport MPEG-4 traffic within the network, the more efficiently it can utilize its available bandwidth and resources.

For the next few years, service providers are likely to centrally acquire content from both MPEG-2 and MPEG-4 satellite downlinks as well as via over-the-air transmissions. While the vast majority of content transported today is MPEG-2, business realities will be a major driver encouraging content providers to reduce their bandwidth costs by encoding content as MPEG-4 before transmitting it via satellite uplink. The number of available satellites is a constraining resource, so content providers will seek to maximize compression before transmission, leading to an aggressive migration to MPEG-4 transmission.

Motorola offers the products and vision that allow network operators to swiftly capitalize on the compression advantages of MPEG-4 while preparing for end-to-end MPEG-4 delivery. Motorola has proven products for encoding, transporting, and transcoding video traffic, and is the world's leading provider of set-tops. By selecting MPEG-4 migration solutions from Motorola, service providers can control their destinies and efficiently migrate to MPEG-4 according to market demand.

MPEG-4 Encoding

The SE-4100/4150 and SE-5100/5160 Advanced Video Coding (AVC) Multi-Format Video Encoders from Motorola are designed for applications using AVC encoding to deliver video at half the bandwidth of MPEG-2. The SE-4100/4150 support SD services, and the SE-5100/5150 support both SD and HD services.

These powerful, flexible, and efficient AVC video compression platforms feature digital program insertion triggers for ad insertion and support a secondary low-resolution proxy output stream for program guide or monitoring applications. They deliver the AVC-compressed MPEG-4 content via existing MPEG-2 transport streams using IP or optional Asynchronous Serial Interface (ASI), making it easy to deploy them into an existing video delivery infrastructure.

Motorola's SE family delivers an entirely new class of video receiver/encoder systems that streamline video delivery operations and direct broadcast satellite operations. The SE family incorporates—in a single 1RU chassis—direct RF signal input, demodulation, decoding, and signal processing with MPEG-4 AVC video encoding. The result is an efficient television distribution design with fewer components, greater reliability, reduced cost, and excellent video quality.

Satellite Receivers/Transcoders

Motorola offers flexible solutions for receiving and transcoding MPEG-2 and MPEG-4 traffic. The DSR-6000 series is the first step in allowing networks to use both MPEG-4 AVC and MPEG-2 compression technologies at the digital headend. Motorola's DSR-6000 follows the success of Motorola's award-winning DigiCipher II® secure content delivery systems to enhance network efficiency for both content and service providers by reducing bandwidth requirements up to 75 percent while delivering high-quality MPEG-2 or MPEG-4 content.

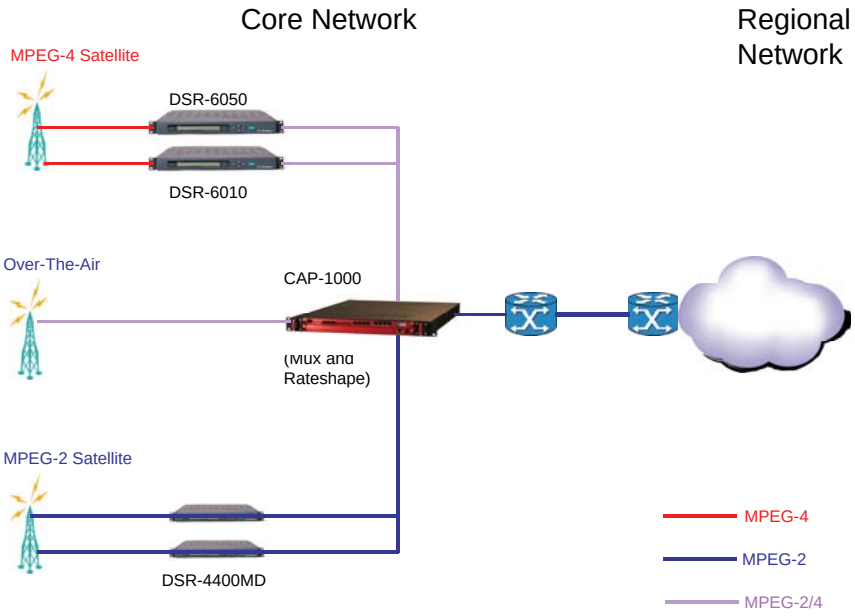

Figure 1: Service providers can progressively migrate MPEG-4 traffic deeper into the network to more effectively utilize bandwidth.

Building on over 20 years of technology innovation in the video industry, Motorola's DSR-6000 series makes the delivery of programming significantly more effective for both content and service providers by enabling network operators to receive programming in bandwidth-efficient MPEG-4. This, coupled with more efficient higher-order modulation technology, reduces satellite transponder requirements by up to 75 percent, allowing content providers to deliver additional high-quality HD and SD programming.

The DSR-6050 model is designed for HD, delivering MPEG-2 HD or SD output derived from an MPEG-4 HD satellite or networked input. The DSR-6010 model will convert MPEG-4 HD into MPEG-2 SD. The Motorola DSR-6000 family of receiver-transcoders extends Motorola's video network delivery leadership by allowing both MPEG-4 and MPEG-2 compression technologies to work within the same network.

The Motorola DSR-4410MD is a powerful digital headend product capable of simultaneous decryption of up to 64 services. It can be deployed centrally as a satellite multiplex decrypter. It also leverages DigiCipher conditional access control, and it can be deployed to support satellite downlinks of MPEG-2 or MPEG-4 content.

Implementing Switched Digital Video
SDV offers tremendous promise for cable operators seeking to more efficiently utilize bandwidth to deliver highly targeted content to subscribers. Motorola offers an end-to-end SDV solution that allows cable operators to leverage their existing infrastructure to offer more channels and to deliver a wide spectrum of niche programming to attract additional subscribers.

On any given portion of the cable plant at any given time, a large portion of broadcast channels are not being viewed by anyone. By streaming only those channels that are actually being watched, cable operators can offer a wide range of niche programming that consumes 50% to 75% less bandwidth compared to traditional broadcast. As an added bonus, cable operators can implement SDV to support the select delivery of both MPEG-2 and MPEG-4 niche content, dependent upon the capabilities of the deployed set-top in the home. Upstream requests from the home for SDV content will identify whether the home set-top supports MPEG-4; if it does than switched traffic can be sent over MPEG-4, otherwise the MPEG-2 content can be transmitted instead. This allows operators a means to introduce new MPEG-4 capable set-tops in their network and operate in a mixed-mode environment with existing MPEG-2 set-tops without having to swap out older boxes.

With innovative end-to-end solutions from Motorola, network operators can optimize core network bandwidth by driving MPEG-4 traffic deeper into the network. In Figure 1, the MPEG-4 satellite downlinks pass through the DSR-6000 platforms to the CAP-1000, and the service provider is able to concurrently support MPEG-2 and MPEG-4 downlinks as well as over-the-air traffic feeds.

Evolving Infrastructure Topologies

Service providers can continue to evolve core and regional network infrastructure to optimize bandwidth utilization by deploying MPEG-4 even deeper in the network. A CAP-1000 serves as a digital splicer on the access network, allowing the service provider to locally insert ad content. The service provider is also able to improve bandwidth efficiency on its access networks by centrally transporting VOD content via MPEG-2 and adding popular VOD titles at the local access networks and transporting them to the edge of the network via MPEG-4.

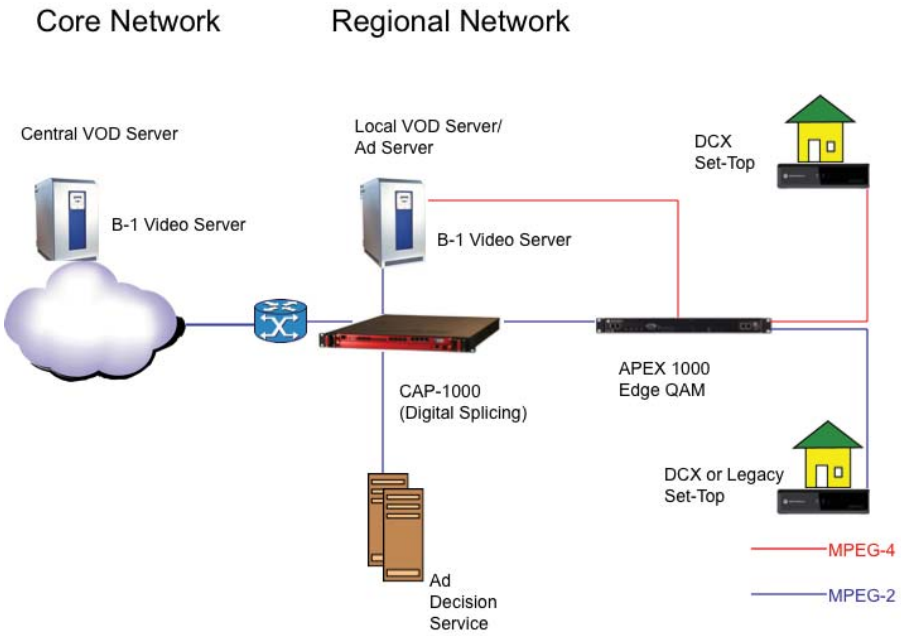

Figure 2: Network operators can efficiently support central and local VOD and ad insertion while preparing to deliver MPEG-4 to the home.

The Motorola All Purpose Edge QAM (APEX) platform is a high-density universal 1 GHz edge QAM solution that can help providers efficiently allocate bandwidth as they deploy Switched Digital Video (SDV). The APEX platform supports standards-based video and high-speed data interfaces, while the physical chassis offers field-swappable QAM modules and redundant swappable power supplies in a cost-effective, low power package. The APEX1000 offers cost-effective and power-efficient multiplexing, encryption, and QAM/RF upconversion in a high-density platform.

Splicing and Switching

Motorola pioneered digital ad insertion in the MPEG-2 domain, and Motorola now supports MPEG-4 AVC with standards-based digital program insertion. Local advertising has long represented a major revenue opportunity. Service providers will not migrate from MPEG-2 to MPEG-4 AVC if their advertising revenues are affected negatively. And those deploying enhanced video services for the first time utilizing MPEG-4/AVC can't afford to ignore this fact when planning their delivery networks. To provide the competitive, quality viewing experience that subscribers expect, program switching

Implementing IPTV

Carriers can turn to Motorola for IPTV solutions. As they build out their IP infrastructure, the last mile can become the bottleneck. For most carriers, the access link to the home will not support MPEG-2 HD services, so telcos are expected to swiftly migrate to MPEG-4 to support the efficient delivery of IPTV services so they can effectively compete with cable operators and broadcast satellite providers. Solutions from Motorola allow carriers to transport MPEG-4 video to the home so they can offer IP-based video channels that attract new subscribers and drive revenue growth. Motorola offers a complimentary line of VIP set-tops which perform MPEG-4 decode functionality while offering SD, HD, DVR, and multi-room DVR experiences within the home.

The VIP family of set tops supports MPEG-4 and MPEG-2 stream processing, but is targeted for telcos and municipalities deploying IP over DSL or all IP networks over fiber.

- The VIP1200 is an all-digital HD/SD set top with IP input.
- The VIP 1216 is an all-digital HD/SD set top with an internal 160 GB hard drive for DVR functionality, and it can record up to four streams simultaneously.

The VIP family can be deployed to support the Microsoft MediaRoom™ user environment or can be configured with the KreaTV™ application development environment to allow third-party middleware and applications to be rapidly integrated. Featuring a native IP return path and IP input, the VIP series is home network ready by adding standard IP-compatible network interface modules or optionally adding the built-in HPNA interface for transmitting IP over existing coax or twisted pair wiring.

and ad insertion must have the kind of payload-aware processing that only true MPEG splicing allows.

Service providers can switch and splice the MPEG-2 traffic flows in the core network using the Motorola CherryPicker® Application Platform (CAP)-1000, which delivers unparalleled quality and reliability for bandwidth management and splicing of both SD and HD services. It has an advanced, IP-centric architecture designed to provide the power, scalability, and reliability required for high-density video solutions. It supports MPEG-4 AVC processing and performs grooming, splicing, and processing intensive statistical multiplexing. The CAP-1000 supports up to 2 Gbps aggregate video stream throughput in a compact, 1 Rack Unit (RU) chassis. It features redundant and hot-swappable power supplies, hot-swappable fan trays, and field replaceable input/output and processing modules to support carrier-class reliability.

The CAP-1000 offers a programmable DSP architecture that is future proof, allowing it to meet evolving standards and emerging application needs over time through simple software upgrades. The CAP-1000 benefits from over 10 years of innovation and field-proven performance in Motorola's Emmy-award winning CherryPicker® product line while embodying leading-edge technology that will provide a high-performance host for mission-critical applications into the future.

Video On Demand

As operators make this transition they will also encounter an increasingly complex mix of MPEG-2 and MPEG-4 SD and HD on-demand content, and will require a VOD solution that easily supports this scenario. The widely deployed Motorola B-1™ Video Server solves this problem by simultaneously supporting both MPEG-2 and MPEG-4 VOD libraries. It is the only 100% solid-state, carrier-class solution for the delivery of on demand video services. The platform's revolutionary solid-state, switch-based architecture completely eliminates mechanical hard drives from the server for video streaming and ingest, instead leveraging the intelligent management of massive amounts of random-access memory.

The result is exceptional performance, carrier-class reliability, massive scalability and industry-leading cost-effectiveness for VOD and advanced on demand services. In addition, as service providers roll out advanced video services the Motorola B-1 provides massive real-time ingest of MPEG-2 and MPEG-4 video for services such as Program Restart, On Demand Ad Insertion, Network-based Digital Video Recording (nDVR) and ultimately, Television On Demand (TOD).

MPEG-4 To—and Within—the Home

Motorola's new DCX family of set-tops supports the decoding of MPEG-4 AVC streams and can be deployed in existing cable networks. DCX set-tops are also "Host" compliant and support M-Card technology for separable security. The DCX set-tops decode both MPEG-2 and MPEG-4 AVC traffic, allowing network operators to deploy them today to new subscribers to support MPEG-2—with the ability to support MPEG-4 in the home in the future without the need for an added truck roll.

- The Motorola DCX3400 is an all-digital, dual-tuner HD Digital Video Recorder (DVR) Host set-top.
- The Motorola DCX3200 is an all-digital, single-tuner HD Host set-top.
- The Motorola DCX100 all-digital, single-tuner SD (HD in / SD out) Host set-top.

The DCX platforms perform MPEG-4 AVC decoding and feature a 1 GHz tuner. They also offer a full set of entertainment interfaces for common digital and analog outputs. When

configured with the optional MoCA™ home networking interface, a DCX platform can serve as a multimedia client for sharing content with other compatible devices in the home over coax cabling. With the DCX product family, residential subscribers can benefit from home networking and multi-room DVR, and the DCX set-tops support DOCSIS® 2.0+ downstream channel bonding. The DCX family of set-tops enables a future-proof migration path that allows network operators to seamlessly migrate to MPEG-4 delivery to the home—and within the home.

Professional Service Expertise

Motorola also offers the professional services that allow cable operators, carriers, and satellite providers to accelerate the efficient migration to MPEG-4. Managing mixed-mode operations is a necessary but complex undertaking, and Motorola offers seasoned network engineers that help service providers worldwide build, operate, and manage MPEG-2 and MPEG-4 infrastructures.

Future Benefits

Increased use of MPEG-4 technologies will deliver immediate benefits by allowing service providers to compress video content and achieve 2:1 or greater performance improvements over existing MPEG-2 compression. The object processing capabilities of MPEG-4 are still largely untapped, and over time engineers will develop more sophisticated algorithms that could lead to even greater compression. As an example, text credits in movies could potentially be recognized as objects and then specifically processed for added compression and efficiencies. Toolsets being developed for MPEG-4 will likely results in even greater compression improvements, perhaps increasing performance to 3:1 or maybe even 4:1 over MPEG-2 compression. Algorithms inevitably improve over time, and engineers and scientist will continue to refine compression algorithms based on an ever-broadening base of real-world knowledge of MPEG-4 deployments.

The use of variable-sized macroblocks and multiple reference frames will further drive advances in compression. With MPEG-4, encoding algorithms can be applied to a variety of sub-macroblock sizes so there will be increased flexibility to efficiently enclose an area of a picture that contains varying levels of detail or motion. In one recent experiment with aerial video footage, Motorola achieved 3:1 MPEG-4 compression by providing increased compression to the blue-sky background behind airplanes in flight. MPEG-4 provides increased flexibility so that organizations can carve out much more detailed mosaics to intelligently recognize potential areas for major compression improvements that deliver the same quality of video at only a fraction of the bandwidth used today.

Turn to Motorola for MPEG-4 Migration Solutions

The migration to MPEG-4 service technologies and its increased use deeper into the network is inevitable. Subsequently, the challenge of leveraging existing infrastructure assets while migrating to MPEG-4 requires the ability to implement flexible solutions that provide the migration path to end-to-end MPEG-4 transport and delivery. Motorola—an established leader in MPEG-2 transport and delivery—offers a wide range of integrated products that allow carriers, cable operators, and satellite network providers to cost-effectively and efficiently migrate to MPEG-4.

Motorola supports mixed-mode operation today, providing network operators with the control needed to benefit from planned migration to MPEG-4. By relying on solutions from Motorola, service providers can purchase products today that support MPEG-2 while providing a migration path to mixed-mode and full MPEG-4 compression capabilities. For more information about MPEG-4 migration solutions, please contact your Motorola account representative or visit www.motorola.com.

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