

# THE FUTURE OF STREAMING MEDIA

Marc L. Tayer  
Aerocast, Inc.

## Abstract

*The final decade of the 20<sup>th</sup> Century was a very exciting one for the North American cable television industry. With major video threats emerging from the Direct To Home (DTH) sector, cable responded quite effectively with its digital cable rollout. Furthermore, with the Internet rapidly becoming a “must have” across America, cable took the high road with the successful standardization of DOCSIS along with market leadership in the broadband segment. More recent initiatives such as HFC telephony, VOD and HDTV are now beginning to gain momentum. Extensive fiber deployment and upgrades to two-way capability became the technical underpinnings for many of these new services.*

*Broadband streaming media is the next big wave and will create dramatic shifts in the way content is created, delivered to, and viewed by subscribers, affecting each constituency along the way. Moreover, broadband streaming media will enable an entirely new category of content, offering limitless possibilities and unprecedented choice for consumers. Operators who embrace broadband streaming will not only enhance their competitive market position, but will also find new revenue opportunities.*

*This paper provides an overview of the broadband streaming media technology and opportunity, contrasting it to the now familiar digital television experience, and including a brief discussion of the various emerging standards and technical elements which make up the broadband streaming media systems of the future.*

## OVERVIEW

The advent of digital television in the 1990s revolutionized the television industry by rapidly multiplying the choice of content available to consumers of DTH satellite and digital cable systems. In fact small dish DTH services such as DirecTV would not have been economically viable in the United States without digital television technology since the content offering from a single 32 transponder analog Ku-band Broadcast Satellite Service (BSS) satellite would have been insufficient to attract more than a niche subscriber base.

Nearly a decade later, with the maturation of digital television occurring due to successful standards such as MPEG-2, increasingly sophisticated and cost-effective set-top boxes, improved customer service and, most importantly, the creation of a critical mass of new programming services leveraging the economic bandwidth benefits of digital compression, the question becomes “what is next?” While MPEG-2 based Video On Demand (VOD), Personal Video Recorders (PVRs) and HDTV are emerging as compelling new offerings, they are evolutionary advances relative to what will become the single biggest leap in video communications since the invention of television itself: broadband streaming media.

Defined as entertainment-quality video delivered over Internet Protocol (IP) networks, enabling content to be viewed in near-real-time relative to the server’s stream, broadband streaming media will finally fulfill the consumer’s ultimate dream of viewing any content at any time. Broadening and further enhancing this category, a new

generation of IP PVRs (integrated into PCs and advanced set-tops) will enable downloadable media and the creation of home networked digital content libraries, making VHS collections, CDs and even DVDs seem as archaic as the LP shelves of the early 1980s.

A confluence of the following factors will bring forth an inexorable broadband streaming media content tsunami:

1. Rapidly Declining Bandwidth Costs
2. MPEG-4 and a New Generation of Open Standards
3. Secure Digital Rights Management
4. Intelligent Content Distribution Techniques
5. Proliferation of Broadband IP Modem Devices
6. Cost Effective and User Friendly Hardware and Software Tools

#### Rapidly Declining Bandwidth Costs

Today it is uneconomical to deliver broadband, and arguably even narrowband, video over the Internet. With Internet backbone bandwidth and content delivery costs in the range of \$500-2000 per Mbps/month (based on peak usage measurements), companies currently delivering IP video to consumers are doing so primarily to promote something else. In most cases, the video is really a form of advertisement or promotion in which the content provider is incurring a cost (or, more optimistically, making an investment) for another purpose, such as keeping eyeballs on a Website, promoting brand or enhancing product awareness, as opposed to providing the video as a product in and of itself.

For example, at \$2000/Mbps/month, assuming roughly 50% bandwidth utilization, a 2 hour movie coded at 750 kbps would cost nearly \$7 per viewer just for transport. This is too high by a factor of at least 10X.

Similarly, with the same transport pricing for an ad-supported 10 minute video encoded at 500 kbps (including roughly a minute of advertising at \$35 Cost Per Thousand viewers, or CPM), the pricing is at least 5X too high for economic viability.

Fortunately, within the next few years it is likely that Internet backbone bandwidth costs will decline to less than \$100 per Mbps/month. At these rates, the cost of delivery on a unicast basis will no longer be an economic impediment, whether the content is offered on an advertising, subscription or pay-per-view basis. Furthermore, Internet bandwidth alternatives such as charging on a per Megabyte delivered basis are becoming increasingly common.

The implicit bandwidth cost of the last mile operator must also be considered. In a digital world, every bit counts and it is logical and natural for a cable operator to allocate its bandwidth toward the maximum cash flow dollars. With VOD becoming an increasingly important product offering for operators, both to generate additional revenue and to differentiate their services from DTH operators (which have been limited architecturally to NVOD but are now wisely deploying PVRs to attempt to close the gap), streaming IP video will ultimately prevail as the predominant VOD technology. MPEG-4 over IP has such substantial bandwidth advantages over traditional MPEG-2 VOD, further strengthened by the immeasurable benefits of being part of the global IP network, that it will become the bread and butter of tomorrow's consumers' media appetite.

## MPEG-4 and a New Generation of Open Standards

For broadcast digital television, one of the attractive features of the MPEG-2 video standard is its asymmetric architecture, with complex encoders and relatively simple (i.e., low cost) decoders. Since the MPEG-2 standard doesn't specify how to build an encoder (so long as the resulting bitstream syntax is MPEG-2 compliant), this design allowed MPEG-2 encoder companies to continually improve their algorithms (and therefore bandwidth efficiency for the content providers) in a fully compatible way with MPEG-2 set-top boxes. In addition, innovations such as statistical multiplexing, which continuously re-allocates bits between multiple video signals sharing a common bitstream pool, allows today's content providers to pack numerous video signals into a single satellite transponder or 6 MHz cable channel. Finally, the asymmetric design of hardware encoders did not impede market growth since the finite shelf space for content on DTH and cable television systems resulted in relatively few programmers leveraging a subscriber base in the tens of millions.

Yet, as far as MPEG-2 has come, it is now essentially a mature technology. For a CCIR-601 half resolution picture (352 x 480) of film material, coding rates of 1.5-2 Mbps are state-of-the-art to achieve entertainment quality, even using the best algorithmic tricks. For HDTV (1080i), good quality can be achieved at rates as low as 12-15 Mbps, depending on the content. And DVDs, using Variable Bit Rate (VBR) coded MPEG-2, typically employ average coding rates of 5-6 Mbps for CCIR-601 resolution.

MPEG-4 is now emerging as the standard for low bit rate video at rates less than 1 Mbps. Using the Advanced Simple Profile, a well-implemented MPEG-4 encoder will enable full screen entertainment quality video

at 750 kbps, perhaps even lower depending on the content. This startling level of bit rate efficiency will dramatically alter the VOD landscape. Since VOD implies an individual stream per user ("unicast" in IP parlance), the phrase "every bit counts" takes on an even more critical meaning versus a broadcast ("multicast") world where a few hundred kilobits per second of coding inefficiency is much less problematic since thousands or even millions of subscribers are tuning in to the same stream.

As with MPEG-2, various MPEG-4 profiles are being established to ensure interoperability. For example, in addition to the Advanced Simple Profile, there is the Simple Profile, the Core Profile, the Main Profile, and a few different Scaleable Profiles. The Advanced Simple Profile appears to be the best profile for streaming media applications, and the Scaleable Profiles will likely experience increasing use over time.

Beyond its impressive bit rate advantage for VOD, MPEG-4 has the additional powerful attributes of interoperability and intrinsic interactivity. In addition, MPEG-4 has wisely included an interface to content protection systems called the Intellectual Property Management and Protection (IPMP) protocol.

One of the most important lessons we learned from the 1990s digital television and cable modem experiences is the critical importance of open standards. Even in an increasingly software oriented world, open standards are the best method for rapid adoption of new products and technologies, multiple sourcing, and simplifying everyone's life from a product management and customer service perspective. Just as the MPEG-2 and DOCSIS standards have aided the entire constituency chain, from content providers to manufacturers to cable operators to consumers, MPEG-4 will perform a

similar role in the IP streaming media arena. In fact, standardization of MPEG-4 is even more crucial since IP is the basis for the first truly global network.

There are three predominant proprietary streaming formats today, RealNetworks, Windows Media Technology and QuickTime, all of which incorporate proprietary video codecs. These formats have improved significantly in the last year and are proving to be effective in enabling streaming media businesses to get launched. Broad proliferation of high quality streaming, however, will require widespread adoption of a standard such as MPEG-4. The current "multiple proprietary format" situation makes for a painful and needlessly complex situation, especially for content providers and consumers, forcing questions such as which format(s) to use, which player(s) to download, etc. While MPEG-4 alone is not a panacea, its adoption will help move the industry toward a common interoperable platform for streaming media. Just as the momentum of MPEG-2 superseded the early proprietary digital television compression techniques, today's proprietary streaming codecs will be pushed aside by MPEG-4.

While MPEG-2 is confined to audiovisual coding and synchronization, forcing a patchwork of proprietary interactive extensions, MPEG-4 is a far broader object-oriented coding standard. MPEG-4 promises to be the holy grail of interactive media, offering content providers the ability to combine real video and audio with synthetic audiovisual objects and text, allowing, for the first time, a unified and integrated standards-based framework for creating super rich interactive content.

With digital television, MPEG-2 video was important but insufficient to ensure full interoperability, and various other standards came into play. Similarly, while MPEG-4 will become the new core of broadband

streaming media, other new and emerging standards will be used in conjunction with MPEG-4 to create an end-to-end system.

- **Audio:** While MPEG-4 allows a variety of audio codecs to be used, the Advanced Audio Coding (AAC) standard is the preferred one for high quality audio. The roots of AAC began several years ago when it was proven within the MPEG-2 standards committee that a surround sound audio system burdened by backward compatibility to MPEG-2 Layer 2 audio (Musicam) would be inferior to a state-of-the-art system without such a burden. Thus began the Non Backward Compatible (NBC) audio mode of MPEG-2, which later morphed into AAC. Offering near CD quality stereo at 96-128 kbps, significantly more efficient than MP3 or Dolby® Digital AC-3, AAC is destined to play an important role in the future of streaming media.
- **Transport:** The MPEG-2 systems layer has become the dominant transport layer for digital television, encapsulating elementary video and audio streams into 188 byte packets, including a 4 byte header and time stamps for synchronization.

Transmission Control Protocol/Internet Protocol (TCP/IP) is the universal transport/network layer for Internet traffic. Related to TCP/IP are various other protocols pertaining to streaming. User Datagram Protocol (UDP) is widely used instead of TCP for streaming traffic. UDP is a more appropriate transport layer than TCP for streaming as it is more of

a broadcast oriented protocol and has lower overhead. Unlike TCP, UDP does not incorporate packet sequencing or retransmissions (through acknowledgments), and doesn't require a set up handshake between the server and client.

- Real Time Protocol (RTP) allows packetized transport of audio, video and data streams. RTP is used in the ITU H.323 standard for video conferencing over the Internet, and is becoming the de facto standard for IP multimedia transport (i.e., of MPEG-1, MPEG-2, MPEG-4, etc.). RTP is used in conjunction with Real Time Control Protocol (RTCP). Together, these two protocols provide such functions as detecting out of order packets, estimation of packet loss and jitter, payload identification, Quality Of Service (QoS) feedback, and multiplexing of media streams.
- Real Time Streaming Protocol (RTSP), used in conjunction with Session Description Protocol (SDP), provides session based VCR-like functions such as fast forward, rewind and pause, as well as metadata information about the program itself. Therefore, RTSP is the protocol which fundamentally allows VOD over IP. RTSP was built on top of Hyper Text Transfer Protocol (HTTP), using the HTTP header definitions and status codes, while adding specific RTSP oriented headers and codes to this list.
- Hyper Text Transfer Protocol (HTTP), the basic protocol used by Web servers for sending

Internet traffic, can also be used to transmit video files to end users. Typically called "progressive download," HTTP video can be thought of as pseudo streaming since it's a form of file download in which the end user can start viewing the video before the entire file has been downloaded. While true streaming has various long term performance advantages, HTTP progressive download has the interim advantages of allowing the use of pre-existing Web servers (instead of dedicated streaming servers), and also getting through corporate firewalls.

The following chart shows the major technological elements of a digital television system alongside the analogous elements of an end-to-end broadband streaming media system.

<b>Technology Element</b>	<b>Digital TV</b>	<b>Streaming Media</b>
Video Coding	MPEG-2	MPEG-4
Audio Coding	Dolby®Digital (AC-3); Musicam	AAC
Transport/ Systemization	MPEG-2	MPEG-4, IP, UDP, RTP, RTSP, MPEG-2
Interface to Content Protection System (DRM)	MPEG-2 PSI (Program Specific Information)	MPEG-4 IPMP
Digital Rights Management/ Conditional Access	DigiCipher® II, PowerKey®	Motorola/ Aerocast™ DRM, Microsoft DRM
Content Guide	TV Guide, TV Gateway, Native guides	Internet publishing directory with search engine and branded portal

## Secure Digital Rights Management (DRM)

Good quality low bit rate innovations such as MPEG-4 present both an opportunity and a dilemma for copyright holders and content distributors. While the notion of a new global distribution channel for video content is inherently attractive, conventional wisdom is that the Internet is an insecure medium. With MP3 Internet file sharing services such as Napster giving content rights holders a definite scare, secure digital rights management (DRM) becomes a critical element for any viable broadband streaming video solution. DRM involves establishing and enforcing rules for the distribution and use of content. Simply put, subscription and PPV oriented content providers cannot risk putting their video assets on the Internet in a way that financially jeopardizes their other revenue sources and distribution partners. And many new content providers will want to utilize DRM in order to monetize their media assets.

Digital rights management is a broader category of content protection than the cable industry's traditional notion of transport-oriented conditional access, with the primary addition being the concept of persistent rights management, defined as the ability to track and protect copying and re-distribution of content from source(s) to destination(s).

A streaming media DRM system should incorporate the following elements:

- Authentication: securely verifying that clients and servers attempting to participate in the streaming process are indeed who they claim to be
- Privacy: rendering the content, as well as other sensitive information, unintelligible to parties which don't have a valid decryption key

- Message Integrity: ensuring, by cryptographic techniques associated with a message, that the message, when delivered to a recipient, was not modified or tampered with
- Conditional Access: controlling the ability of individual subscribers to view or listen to content on a subscription, PPV, or other restricted basis
- Persistent Copy Protection: applying rules which dictate who can do what to content with respect to copying or re-distribution, as well as techniques such as watermarking and fingerprinting which can help trace the source of the content

In designing a state-of-the-art streaming media DRM system, proven and existing standards should be employed such as the recently adopted Advanced Encryption Standard (AES), represented by the powerful Rijndael encryption algorithm. A combination of public key and symmetric key techniques should be used. Public (asymmetric) key cryptography involves a public key, which is generally known, used in conjunction with a different private (secret) key. With symmetric key cryptography, the encryption and decryption key are the same, and this key must be kept private and secret. In general, Public Key Infrastructure (PKI) techniques should be used for cryptographic applications that are less time-sensitive, such as initial set-up and authentication, while the latest symmetric key techniques should be utilized for time-sensitive applications such as payload encryption.

Major system features should include subscription, pay-per-view, pay-by-time, unicast, multicast, parental rating controls and location-based access, as well as the ability to control copying and re-distribution.

## Intelligent Content Distribution

Delivery of digital television content is a mature and fairly straightforward process including satellite links for backhauls and distribution, microwave links, signal collection in headends, and modulation and upconversion for re-distribution through the cable plant. Additional intelligence is required in order to repackage individual digital programs from multiple transponders into a single cable multiplex. In the MPEG-2 digital TV world, with the emergence of VOD, PVRs and user-based preference schemes, content delivery will become incrementally more refined.

But with IP streaming media, intelligent content distribution takes on a whole new meaning, heralding a hyper dynamic system of global, national, regional and local networked VOD in which content will be cached where and when it is most demanded, while preserving for content providers the flexibility to broadly distribute content if that is what they desire and can justify economically. A key issue for IP streaming media is edge caching (storing and serving content from a point as electronically close to the end viewer as possible). But mere edge caching without intelligent content distribution is tantamount to distributing magazines to newsstands around the world without regard to the particular languages, tastes or preferences within each localized vicinity surrounding the newsstand.

The following concepts exemplify intelligent content distribution in the context of a next generation broadband streaming media system:

- Pre-positioning: moving a streaming content file in its entirety to a pre-selected set or subset of edge servers. This method will be used by content providers which are reasonably confident that one or more subscribers in each edge server vicinity will want to view the content, and are therefore willing to invest upfront for broad distribution and storage.
- Partial pre-positioning: moving a portion of a streaming content file to a pre-selected set or subset of edge servers. This method is more conservative than full pre-positioning and will still mitigate the phenomenon whereby the first viewer of a piece of content is penalized by drawing the stream all the way from the origin server or from a non-optimal edge server. Various tradeoffs can be contemplated between how large of a portion of the content object to pre-position at the edge(s) relative to the projected network latency issues surrounding streaming the remaining non-pre-positioned portion of the content object.
- Demand based caching: For broad libraries of content, as well as niche, local or individual self-published content, it may make more sense for the object to remain at the origin server site until a subscriber requests it from the portal or directory. Then, the object would begin caching at the preferred edge server, and the initial requestor would have an acquisition penalty. Subsequent viewers from the same edge server would be able to view the content with high performance and without delay.
- Edge server selection: With a network of edge servers, the process and method by which selection of the best edge server at

any given time is a fundamental part of intelligent content distribution. Various techniques exist and are being refined, some of which are significantly more precise than others in their ability to select the electronically closest edge server.

Additional factors pertain to intelligent content distribution such as how long to store an object at an edge server (e.g., absolute time period, pre-determined time period from the last time the object was requested, etc.), as well as the integration of the intelligent content distribution system with the DRM system.

#### Proliferation of Broadband IP Devices

There are now over 5 million broadband Internet subscribers in the United States, the majority of which are cable modem users. This figure is expected to grow to at least 30 million households by 2005. In addition, cable modems are increasingly being integrated into digital set-top boxes. Therefore, over the next few years, broadband Internet access will become not just a PC-centric phenomenon but also a TV-centric enhancement, and streaming media will be the driving force which accelerates and sustains this trend.

Beginning with the advanced set-tops being introduced in 2001, increasingly more powerful microprocessors will be incorporated allowing many additional functions and applications to be implemented in software. In addition, as standards such as MPEG-4 take hold, cost-effective dedicated hardware devices such as MPEG-4 circuits will be introduced.

#### Cost Effective and User Friendly Software and Hardware Tools Leading to an Explosion of Internet Content

Perhaps the greatest promise of broadband streaming media is that the finite shelf space shackles of the television world will finally be torn down, allowing virtually anyone to be a content provider. Of course business models and the development of audiences and viewers will still ultimately determine success, but the growth in content availability enabled by broadband streaming media will be mindboggling and exponential relative to the impressive increase in content offerings which occurred due to the move from analog to digital television.

With broadband streaming media, each and every content genre (sports, education, travel, culture, music, kids, health, cooking, weather, just to name a few) will become fully represented in a way that television cannot replicate. The concept of narrowcasting and the availability of niche and special interest content will be taken to a whole new level. The local content enabled by streaming media will give operators a powerful new content weapon in the race against DTH providers, upstaging the limited “local into local” capability provided to DTH subscribers.

This is not to say that streaming will replace broadcast television; it will not. Television will remain the superior technology for mainstream popular content for many years to come. Instead, streaming will complement television in a synergistic way that is only starting to be conceived.

Helping this trend along is the increasingly cost effective and user-friendly availability of software and hardware tools. For example, the new generation of Digital Video (DV) camcorders is not only starting to become affordable, but also is just as easy to use as yesterday’s analog camcorders.



These DV camcorders have standard IEEE 1394 (Firewire/i.Link) interfaces for PCs, allowing the captured motion video to easily be transferred to hard drives in PCs, where the content can be edited and manipulated with software which is becoming less expensive, more user friendly and more powerful every day. Finally, software based encoding, streaming, distribution and directory tools will allow this content to be made available to broad or narrow audiences on a global basis.

### Conclusion

A combination of new technologies and economic conditions is materializing which will usher in a new era of broadband streaming media. Broadband streaming media is unprecedented in its ability to deliver on demand (and live) content of every shape and form. It is important and timely for operators to weigh in on important issues such as the MPEG-4 and RTP/RTSP standards. The emerging MPEG-4 standard, secure digital rights management, and intelligent content distribution are among the most prominent of the technologies that will form the foundation for this exciting new media category. Enormous opportunities await the content providers, technology companies and operators that embrace and tap into the future of streaming media.

### Contact Information:

Marc L. Tayer  
Senior Vice President, Business  
Development  
Aerocast, Inc.  
5744 Pacific Center Boulevard  
San Diego, CA 92121  
(858) 404-6211  
mtayer@aerocast.com