IS MPEG-2 OUR NEW LEGACY?

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Abstract

Cable operators have been looking at advanced video codecs in order to make more bandwidth available to meet ever-growing user demands on cable networks,

This paper investigates the issues related to introduction of a new video compression format in cable networks and how it can co-exist with "legacy" MPEG-2 deployments.

INTRODUCTION

The introduction of digital cable services using MPEG-2 over 10 years ago was done to meet several objectives: ability to provide hundreds of television programs, reduce capex and opex related to acquisition and distribution, to name a few. The transition from analog to digital required plant upgrades, new encoders, and new STBs along with a revolutionary way of thinking. Today, MPEG-2 set of standards forms the core of audio, video and transport protocols used in the digital cable delivery system [1,2].

Over this same decade, user requirements have changed along with advances in video compression technology. Recently, several new video codecs have been introduced (e.g. WM-9 and MPEG-AVC/H.264). The powerful message of these codecs is hard to ignore: 2-to-3 times the compression efficiency, Digital Rights Management support and increased interactivity with the content. End users are now interested in "my 500 channels" rather than the standard "500 channels" on their cable networks. Proliferation of new digital services such as VOD, HDTV, DOCSIS, VOIP has increased the need to be able to send more bits on the same pipe.

Does the bandwidth crunch necessitate moving to new video compression technologies? Yes and no. In this paper, we present the case that new compression formats should be looked at as complementing the MPEG-2 based deployments in the near term, not replacing them. The introduction of new video (and audio) codecs can act as a part of a bandwidth reclamation strategy instead of a complete overhaul of a cable network.

In this paper we first list some bandwidth savings strategies in cable networks that can help reduce the bitrate needs without abandoning MPEG-2 based deployments. Next, we take a look at the issues involved in introduction of new video compression formats. Unlike the analog to digital transition, only new encoders and STBs are required, but plant upgrades are not necessary. This allows for new and old video technologies to co-exist and many of the ideas originated in the earlier transition can be leveraged again.

HOW FAR CAN MPEG-2 GO?

MPEG-2 video standard specifies syntax for compressed video bitstream, but does not standardize an encoding algorithm to generate it. Over the years, better encoding schemes have yielded superior picture quality at a given bitrate using techniques such as improved pre and post processing, smoothing of motion vectors, better rate control (bit allocation) multi-pass encoding and so on. Compared to the early days of MPEG2, the typical bitrate required for broadcast quality video compression has gone down significantly through competitive processes built into developing advances in video encoding marketplace. However, it is interesting to note that certain applications such as VOD have associated business agreements that dictate the bitrate to be constant (e.g. 3.75 Mbps) irregardless of the advances in encoding techniques.

Video compression experts generally agree that current state of the technology is such that new encoding techniques to produce MPEG-2 video streams will probably not produce too much further improvement for entertainment quality television programs (See Figure 1). Due to the maturity of the MPEG-2 codec, most significant coding efficiencies at the main profile/main level (MP/ML) have already been explored through the competitive encoder development marketplace .

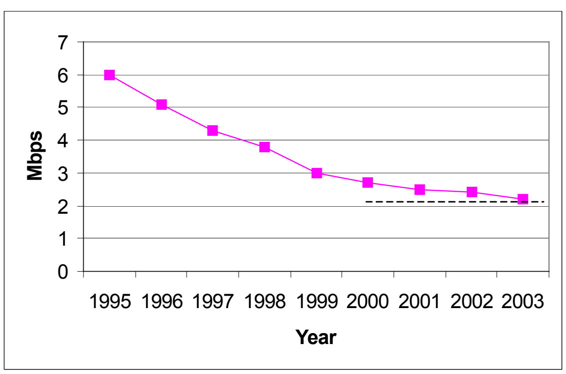

Figure 1: MPEG-2 Generational Encoder Improvements

There are ways to extend the coding potential of MPEG-2 by adding new tools and creating new profiles. In the last few years, researchers have been looking at compression techniques beyond MPEG-2. By way of example, some of the potential new additions to the existing tool-kit of video compression techniques include:

- Multiple reference frames for prediction.
- Variable block size for motion estimation
- Special prediction modes for fades
- 1/4th pixel motion estimation.
- Multiple directions of prediction for I-macroblocks,
- Loop filter to control propagation of error,
- Usage of arithmetic coding.

Adding these new tools, requires extensive modifications of the MPEG-2 standard and the creation of new products. In essence it would be almost equivalent to creating a new coding standard to handle these changes. In fact, some of the coding gain in advanced codecs come from including these tools [3].

It should be noted that various alternatives exist to reclaim bandwidth other than changing the video compression codec, and may be easier to deploy. A quick list includes:

1. Higher QAM constellations (64 to 256: ~33%/QAM)
2. Shift analog PPV services to digital (10X/QAM)
3. Switched broadcast Service (~1x/QAM)[4]
4. Stat mux MPEG-2 VOD (~25%/QAM)
5. Convert all (most) analog to digital (10X/QAM)

STATE OF COMPETITION

Not surprisingly, the need for bandwidth is felt by DBS operators too. Due to the need to carry local programming, offer HD services and making bandwidth available for personalized 2-way video services, satellite operators have been looking at various options including migration to higher constellation modulation, use of turbo codes and adoption of advanced video codecs. Satellite operators have very little margin left in reducing per-channel bandwidth used by their MPEG-2 video programming and it is inevitable that they have to commit to a new compression standard in near future. However, to date, there are no announced plans of migration to a new video codec.

With MPEG-2 technology, DSL providers have not been able to establish a firm foothold in the video delivery market. The desire to adopt an advanced video codec for video delivery has also been reported in the DSL industry because it can open up these markets. Recently approved ADSL-2 standard enables transmission of data at 1.5 Mbps over existing existing phone networks [5]. This channel rate is not enough for entertainment quality video transmission if one is using MPEG-2 compression, but is plenty for advanced codec based transmission. However, High Definition programming still poses a problem because 1.5 Mbps is not enough bandwidth for HD transmission, even for advanced video codecs. Clever attempts have been made to meet that need by a very fancy arrangement of multiple phone lines. For example, UK based Net-to-Net Technologies and Tandberg TV experiment using two lines ADSL loop bonding, as referenced in an Internet report [6].

Another recent shift in business model due to availability of high bandwidth DOCSIS is the content providers directly doing business with consumers by bypassing the need to have business relationship with network operators. Currently, there are only a couple of high profile (and many smaller) TV-over-the-Internet type services available. Two things to note here – decoders used for these services are typically software-based (WM9 or Real), with DRM enhancements to the liking of each content provider, and video compression algorithms used do not need to be standardized (the exception to this is targeting to portable personal devices). Over time, as the average bitrate needed to deliver entertainment quality video decreasesthe take rate on these services will rise. Whether or not this is an opportunity or threat to cable operators remains to be seen [7].

Wireless network operators have also recognized the new market opportunities in being able to offer video services. Recently, there is a renewed interest in MMDS technology (e.g. WiMAX consortium) that provides fixed wireless broadband access to subscribers. At the bitrates of transmission (1.5 Mbps), advanced video codec will be the logical choice for entertainment quality video services. It is too early to speculate if the wireless operators will provide data and voice only or if they will provide data, voice and video with broadcast television quality video services.

In terms of ability to offer converged services (streaming, video conferencing, video cellphone, and traditional video using same codec and protocols) MPEG-2 transport and video technology is at a disadvantage. Migration to advanced codecs and new standards potentially gives a competitive edge to the above network operators by enabling converged service offering.

IMPLEMENTATION COSTS

Due to the broadcast nature of the video signal, and number of decoder units; the cost of equipment on the decode side far outweighs the costs associated with upgrading encoding equipment. We therefore only talk about cost of implementation related to the set-top box side.

In anticipation of a future move away from MPEG-2 technology to another video codec, several IC manufacturers have already started building their decoder ICs based on flexible platform (e.g. TI, Equator, ST, Philips etc.) Obeying Moore's law, providing backward compatibility becomes a less pricey option.

As an example, MPEG decoder ICs are sold at approximately <$12 price range. Current MPEG4 decoder pricing is very high (almost a $15 premium over MPEG2 (MP@ML) only decoders), but the premium is expected to go down to less than 7 dollars in 3-4 years [8].

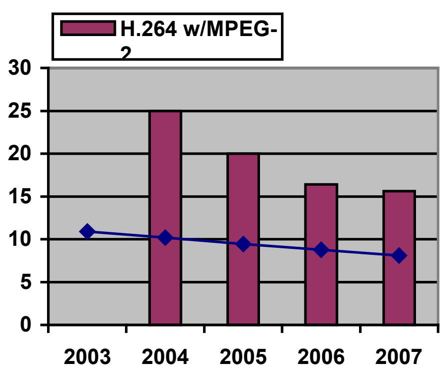

Figure 2 Average Sale Price of decoder IC (Courtsey: In-stat/MDR)

New design and advances in hardware such as Media processors, VLIW processors are changing the traditional "hard-coded" nature of video decompression platform, making it more flexible to adapt to new video codecs.

IS MPEG-2 VIDEO REALLY LEGACY?

The transition to a new digital video codec is not the same as the earlier transition from carrying just an analog Cable TV signal to using a new digital transmission platform. The earlier digital migration was much more physically involved than just replacing a video codec; fortunately this time there is no need to rebuild the digital platform. The network infrastructure put in place for establishing MPEG-2 technology is still useable; the cables, connectors, amplifiers, and transport mechanisms are already in place and can be used to support carriage of both codecs. The concepts of modulation, multiplexing, buffering, insertion, and caroseling can be reused and intermixed with the new video codec.

The real analog legacy that still exists today is not the plant and equipment upgrades; but the reluctance of a sizeable group of people (approx. 63 million paying in 2003 [9]), who get basic cable service to all the TVs in their household for one low fee, to switch to a digital service that requires a box for each TV. The fear is that they may opt out of cable altogether. Alternatively there is constant pressure to shift from analog due to extensive piracy, bandwidth demands, and less robust security mechanisms. This 'analog' legacy is what in one part is creating the bandwidth crunch on plant systems and much study through the "all-digital efforts", including using new digital video codecs, are being considered for resolving this problem. The important thing to realize is switching from an MPEG-2 Digital Video platform to a new type of digital video codec does not create the same type of legacy and may, in part, actually be a solution to this analog one.

The challenges created by switching to a new digital video codec are buying new encoder equipment at headends or regional centers and replacing the millions of digital STBs already deployed. The most significant cost is replacing these STBs (approx 29 million in 2003 [10]), but this could be argued as not insurmountable and actually somewhat less of an effort than what has been launched in the past. There are a number of strategies that can mitigate and justify these costs, but much of this depends on being able to carry both types of codecs in the same cable plant and developing new boxes that can decode both MPEG-2 and the candidate digital video codec. With this and the inherent advantages of the local distribution in cable systems, cable service providers can take several steps to ease the burden of this transition:

- They can deploy new services on a region-by-region basis using an ROI to justify the deployment of new STBs.
- The type of video service is agnostic to kind of digital codec used. This means that MPEG-2 can initially be used with a deployment of service to build up demand to justify a box upgrade and then switch the codec used for the service.
- Alternatively new codecs can be introduced in new tiers of services.
- Initial deployment of a few STBs to be used in a slow rollout can help decrease the new STB costs for future larger rollouts.
- Existing MPEG-2 only STBs can be redeployed in other parts of the system to assist in digital upgrades.

New advanced codec products can be designed to decode both the new codec and MPEG-2 given an additional 10-15% extra performance in the chip. Though the new codecs are not backwards compatible with MPEG-2, the product can effectively support both. The STB can be deployed to operate on traditional MPEG-2 systems. As the new codec gets deployed on the plant, the same box can be used to decode these new services. This strategy can allow MPEG-2 to be complemented by the newer codec and can allow services to exist before a decision is needed to switchover the codec.

There are already a large number digital MPEG-2 STBs out there, but this number will continue to grow due to a dramatic increasefrom demand of MPEG-2 HD Boxes. Given that new product deployments will be at least 1-2 years away, there will be a significant installed base of MPEG-2 boxes. Any new codec will have to work in complement with the MPEG-2 existing technology and services for a cost-effective transition. Some factors to consider for this would be:

- New boxes need to bring in additional revenue
- Room for bandwidth needs to be made. This can happen through bandwidth reclamation strategies as mentioned previously.
- Analog PPV services must be phased out by replacing these boxes with MPEG-2 STBs

A place on the cable plant where a total replacement of MPEG-2 with the advanced codec could be beneficial, and less of a hardship, is in the backend storage and transport systems. With the projected increases of Video-on-Demand (VOD) cable services, larger amounts of content will need to be stored, replenished and distributed in the backend plant. A content catalog of 10,000 hours with 25% of it being replaced once a week would require at least a continuous 56 mbps transport link to the headend along with 17,000 GB of storage (this does not include storing multiple copies or transport to edge servers). To deal with this, more server farms will need to be added along with leasing of more bandwidth to transport content to one or many headends. These costs can be reduced through the use of advanced codecs that will effectively halve the storage and transport needs. To take advantage of these cost savings real-time transcoding technologies between the new codec and MPEG-2 should be encouraged.

EXAMPLE USAGE SCENARIO: NEW VOD SERVICE TIER

The introduction of a new video codec needs to be part of an overall bandwidth reclamation strategy. A single RF QAM Channel can have a tremendous range in video capacity depending on how it is being used (see Figure 3). Effective management of this bandwidth can lead to new services as well as a cost-effective way to deploy an advanced video codec. There are many ways to accomplish this, but this section will attempt to describe one possible approach.

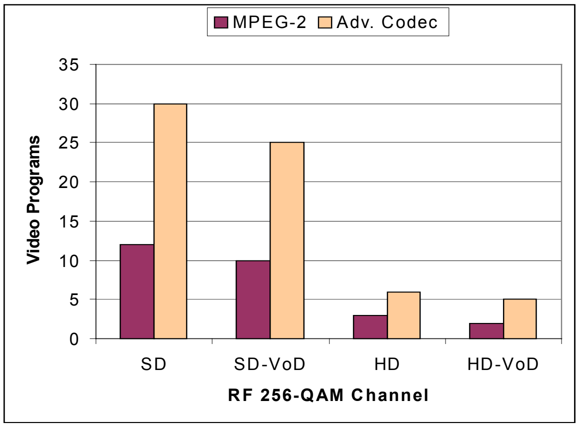

Figure 3: Codec Video Program Capacity for Single 256 QAM Channel

Presently VoD services (projected to be a 4-5 billion dollar market by 2007 [11]) contain several different types of streams that have radically different bandwidth behaviors. Two potentially bandwidth intensive services are High Definition (HD-VOD) deliveryand Subscription Video on Demand (SVOD). A High Definition program in MPEG-2 requires approximately 4 times the bit rate of the same channel in SD format. Besides needing a larger bit rate, HD-VOD creates a demand on bandwidth resources by effectively blocking potentially 4 or more SD streams for each HD stream in use. The SVOD service also creates a demand on bandwidth resources by effectively blocking pay-per-transaction SD streams especially when 'channel surfing' behaviors occur. As the take-up on these services becomes more popular, a need to create a bandwidth resource policy based on these different behaving streams will be necessary.

There are several new revenue sources to cable being captured by the on-demand services: One is replacing the local video store ("watch a movie without the late fees"), the other is competing against the burgeoning PVR market but with some extra features like an unlimited hard drive, access to unaired content, and never needing to record a show. The High Definition offering basically provides a "gotta have" service that can increase customer loyalty ("I gotta have a feed for my new HD set and cable has it"). The problem is on the cable plant, the bandwidth is disproportionately dished out. An HD request can replace 4 or more SD requests, but the price is not that much different. The SVOD service can take up bandwidth that could have been used by someone who didn't want to go to the video store to see the latest movie releases. These situations can create either more contention or a disproportionate increase in bandwidth demand on the node level to accommodate peak use. Some ways to deal with this is to limit the amount of HD requests and constrict the size of the content catalog of an SVOD service to allow enough take-up rates in the traditional MOD service. An alternative to this is to create a new tier of on-demand services.

This new tier would have a combined local SVOD offering with an HD-VOD service that requires a new STB capable of doing both MPEG-2 and the new codec. The lower on-demand tier for renting SD movies would be supported by MPEG-2 and the new tier would be supported by the new codec. With the doubling of bandwidth from the new codec, the SVOD service can have an expanded and localized content catalog with a predictable monthly income source. Additionally enabling HD-VOD on this tier provides incremental income other than the monthly fee as well as freeing up bandwidth on the lower on-demand tier for the SD MPEG-2 movie rental market.

By creating this tier, a new box with the advanced codec can be deployed with a trackable ROI instead of a pure capex expense. A tier becomes identified which offers a value to the customer worth the additional monthly upgrade fee whether the subscribers has an HD set or just wants the additionally content on SVOD. In effect it ties the deployment of the new boxes with a new revenue source while reducing the bandwidth demands on the lower MPEG-2 tier. Consequentially, this frees up the lower MPEG-2 tier for capturing more of the SD video rental market whose customer base will be largely those with existing MPEG-2 only STBs. Since this is a node-based service, the new tier (and new replacement boxes) can be targeted to specific areas or rolled out region-by-region. Furthermore it creates a type of bandwidth policy that can relieve some of the future pressure on a mixed on-demand tier. Lastly, the deployment strategy addresses the on-demand segment rather than the broadcast segment which for cable is more of an area for future growth. Again this is only one type of usage scenario for initially deploying a new codec, but there are others.

CONCLUSION

In this paper, we have discussed issues and challenges related to the introduction of advanced video codecs in MPEG-2 based digital cable networks. One of many possible deployment scenarios is discussed in details.

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