SEAMLESS, SCALABLE HDTV ROLL-OUTS OVER TODAY'S HEADENDS

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Abstract

Offering HDTV programming is a necessity for cable operators competing with satellite and terrestrial broadcast television alternatives. However, digital cable faces several challenges in broadly replicating the HDTV services currently available via alternatives:

- *Maintenance of equal video quality, satisfactory to broadcasters, content creators and subscribers, while maintaining cable plant bandwidth efficiency*
- *Compliance with carriage of data associated with programming according to the PSIP standard and openly accessible by consumer electronics devices*
- *Responsiveness to programming changes by on-air broadcasters whose content is being mapped onto cable plant, such as when sudden shifts are made in use of bandwidth from an HDTV feed to several SDTV feeds*

This paper describes a comprehensive way to roll out full HDTV experiences in existing headends. It suggests channel line-up scenarios that achieve bandwidth efficiency with high quality content through advanced video bit rate adaptation techniques, effective multiplexing of PSIP data, and real-time intelligent responsiveness to broadcaster changes.

MAINTAINING CABLE PLANT EFFICIENCY WHILE ROLLING OUT HDTV

This section justifies bit rate adaptation techniques as a solution to overcome bandwidth challenge while scaling up HDTV roll-outs. It suggests channel line-up scenarios and implementations that maintain video quality over cable.

Existing bit rate constraints prevent scaling up of HDTV service

The Advanced Television Systems Committee (ATSC) gave birth to HDTV and 8-VSB (8-level vestigial sideband) modulations standards. At that time ATSC adopted the VSB transmission because of its "large" bandwidth, which is needed to transmit HDTV programming off air. In December 1996, the FCC approved those standards to replace the analog standards of the NTSC. The 8-VSB mode supports up to 19.4 Mbps of content and drives the maximum bit rate allowed for HDTV streams.

MPEG-2 technologies have brought encoders a long way during the last decade to offer similar video quality at lower bit rates benefiting from statistical multiplexing techniques. Such techniques take advantage of the inherently variable bit rate of video feeds, such that when multiple feeds are combined, it is highly unlikely that most or all will experience intensive action simultaneously, and in fact bandwidth peaks for some will usually correspond with troughs for others. Unfortunately, such techniques are predominantly employed for SDTV and little is expected from statistical multiplexing of HDTV feeds because only one or two feeds are carried per multiplex.

The following table compares the maximum number of HDTV versus SDTV feeds carried today using various modulation approaches. It also shows how broadcasters efficiently carry one HDTV feed versus other multiplexing alternatives.

	Modulation	Theoretical Rate	HDTV Carried at Near Constant	SDTV Carried with Statistical Multiplexing
Broadcaster	8-VSB	19.4	1	
Cable	64 QAM	27.0	1	7-8
	256 QAM	38.8	2	10-12
Satellite	QPSK	27	1	8-12
	8-QPSK	40	2	12-20

Cable operators face a severe challenge in scaling up HDTV while accommodating for over 19Mbps per HDTV stream, as defined per ATSC standards. This is on top of the challenges of bringing together content sourced from broadcast and satellite feeds, with their distinctive formats, onto a single plant.

Unless massive efforts such as cable plant upgrade or aggressive analog reclaim are undertaken, the HDTV constant bit rate approach won't scale up in a world of fast growing double-digit available HDTV programs. MPEG-2 bit rate adaptation techniques, also called rate shaping, can address those problems.

<u>HDTV rate shaping optimizes statistical multiplexing techniques – it's not all about crushing bits!</u>

Rate shaping describes bit rate adaptation techniques applied to MPEG-2 encoded streams, to further enhance bandwidth efficiency. This technique can substitute for decoding-encoding operations that are expensive, space consuming and ultimately harmful to content quality.

Accommodating various transport alternatives, rate shaping also adjusts the necessary bit rate to "bridge" HDTV bit rate from satellite and off air delivery onto cable plant. By doing so, HD rate shaping removes fixed bandwidth allocation constraints imposed by ATSC standards. The technique considers and accommodates cable plant transmission capabilities for greater bandwidth efficiency, without the harmful effects of decoding and re-encoding. HD rate shaping does not blindly steal bits to squeeze more into a channel, so video quality does not suffer for bandwidth efficiency.

In the case of three HDTV into one 256QAM channel, the rate shaping operation does not reduce all streams 33% to squeeze one more program. Instead bit rates are dynamically driven by incoming content complexity. Depending on content, economic bit rate reduction per program can be as low as 10% and up to and beyond 50%, while maintaining identical perceived video quality to original sources.

By taking multiple outputs of this process from multiple sources and packing them together, varying bit rate results in cumulative bit rate efficiencies at desired video quality. This process, also called statistical re-multiplexing, outlines how cable operators can accommodate their own bandwidth efficiency by moving away from the near constant HDTV bit rate expectations traditionally imposed on them.

Statistical re-multiplexing is utilized by cable operators for SDTV feeds already and can be applied to HDTV feeds similarly. However because of the nature of available HDTV content and its video quality emphasis, caution is required when implementing HD rate shaping in the headend.

<u>Applying content intelligence in rate shaping.</u>

When deploying rate shaping technology in cable headends to gain bandwidth efficiency, it is important to stay competitive with alternate sources. As mentioned earlier, content intensity drives bit rates in statistical re-multiplexing operation. Because cable operators have the freedom to choose specific channel line-ups, they can optimize for certain scenarios that will maintain video quality compared to alternatives.

As an example, sports, movie and news content introduce different complexities that drive the bit rate reduction allowances differently in HDTV. The higher the complexity is, the less likely is bit rate reduction to occur, and vice versa. As a general rule, avoiding excessive content within a re-multiplexing pool will allow optimum video quality and greater bandwidth efficiency.

Certain statistical re-multiplexers have the ability to combine both HDTV and SDTV feeds. Benefits include offering granularity at which the bandwidth efficiency is reached independently from content complexity. Combined with priority mechanisms, there are cases where the HDTV bit rate can remain untouched while bandwidth efficiency is gained by removing stuffed packet (nulls) for SDTV channels. This technique is called pass through mode as it exactly replicates the on screen HD content and quality level as at the peak bit rate, while finding unused bandwidth in stuffed packets that can be allocated to other traffic.

Fig. 1 below outlines HD and/or SD channel line-ups and their respective bandwidth efficiencies in the example of 256QAM cable plant. The efficiency gain is the amount of content carried on a QAM channel versus a constant bit rate alternative of two 19.4 Mbps HDTV feeds. For purposes of this analysis, the general guideline applied is that six SDTV feeds conventionally consume the same bandwidth as one HDTV feed.

The figure also suggests deployable scenarios under the condition justified by identical subjective video quality comparison to alternatives sources available in the field.

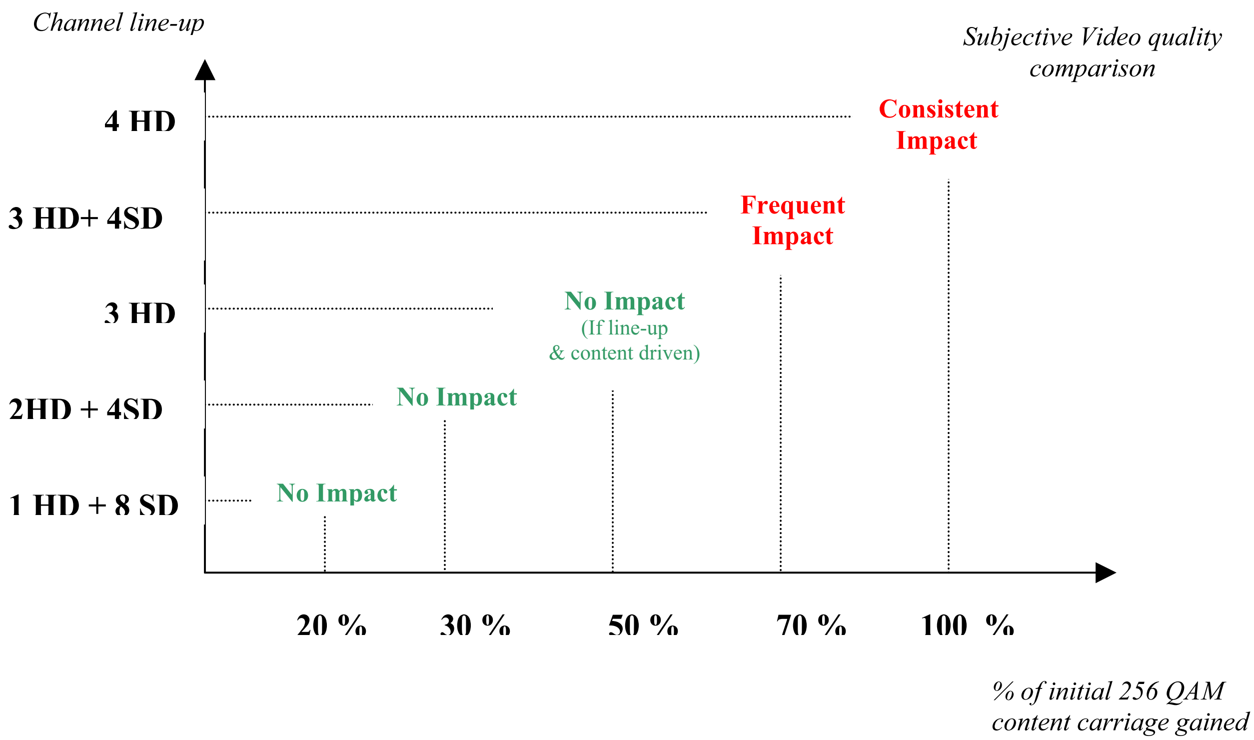

Fig. 1: Bandwidth and quality impact of rate shaping and statistical multiplexing alternatives.

By appropriately implementing rate shaping with proper channel line-up, cable operators can achieve up to 50 % bandwidth efficiency gains, while preserving similar video quality to alternatives. Beyond 50%, video quality can be impacted, and it is recommended that operators make considered decisions about deployment.

PSIP SUPPORT ON THE CABLE PLANT

This section addresses cable-ready television support through the implementation of the PSIP format, including compliance with industry standard agreements.

What is PSIP and why is it needed?

PSIP (Program and System Information Protocol) has been standardized by the ATSC to allow tables of information to be transmitted along with the associated video programming. PSIP data are originated by broadcasters and are required by some ATSC receivers to tune to the correct digital channel.

Set-top boxes used by cable operators do not require PSIP to tune to a channel, but the growing availability of retail market cable-ready digital televisions requires PSIP presence on the cable plant to guarantee proper tuning. Besides tuning, PSIP tables contain other important information about the programming, such as branding and electronic program guide data.

Consider a local station that offers three different shows during the day. Digital televisions allow viewing the analog service as channel 65, for example, and the three others as channels 65-1, 65-2 and 65-3, even tough the digital broadcast is technically on channel 66. The main number indicates that those channels belong to the same broadcaster whether they are analog or digital. In this way the analog branding is preserved in the digital world.

The electronic program guide (Fig. 2) is the navigation interface provided to the user to tune to a channel, specifying timing and event description. PSIP carries tables that can be used by cable-ready televisions to build the electronic program guide. This function is often seen as a benefit of converting to digital by the user, and will be provided automatically by cable-ready televisions as long as PSIP tables are available. The ATSC PSIP standard requires that a minimum of the next 12 hours of program information be available in advance, although PSIP can offer up to 16 days of programming.

Fig. 2: Electronic program guide representation.

<u>Complying with NCTA-CEA agreement.</u>

The emergence of cable-ready televisions, with their PSIP support, call to question digital cable interoperability with ATSC PSIP standards. There is a large number of standards, agreements, specifications and FCC rules that relate to the interoperability of consumer electronic products with cable-ready televisions (like the one shown in Fig. 3), but the cable and consumer electronics industries have taken important steps towards achieving interoperability by establishing the NCTA/CEA technical and PSIP agreement.

NCTA and CEA negotiations resulted in an agreement that provides a consistent set of standards that enable cable-ready televisions to be connected directly to a cable plant without the need for a set-top box. The agreement section relating to PSIP addresses television receivers that do not have a security module (Type 1 Television).

During the negotiation, the cable industry made clear that carriage assumes the availability of PSIP data from the content provider, and that it would be prepared to support carriage of PSIP information when made available from the content provider in accordance with the agreement. CEA agreed with the document. The agreement also specified mandatory/optional PSIP tables to carry on the cable plant while recommending standards to overcome implementation issues. For more information on NCTA\CEA agreement specific to PSIP, refer to ATSC A/65 and SCTE DVS-097 standards.

Fig. 3: Mitsubishi cable ready TV – WS55909.

<u>PSIP agreement implementation in the headend.</u>

Cable operators will need to obtain necessary hardware and software to implement the NCTA/CEA agreements. Whether two broadcast signals or more are combined in a single transport stream for delivery using 256QAM or 64QAM, the re-multiplexing operation (with or without rate shaping) will require rebuilding the PSIP information.

Sent in-band with the video, PSIP table implementation requires a platform that can combine both video and data. In some cases, rate shaping can be required to make room for data when bandwidth of incoming video consumes what's available.

ACCOMMODATING BROADCASTER MULTICASTING HABITS

This section addresses how off-air multicasting can impact cable service, and proposes an alternative approach to multicasting through automatic response.

<u>What is multicasting?</u>

Multicasting occurs when broadcasters suddenly shift use of bandwidth between various combinations of HDTV feeds to SDTV feeds. The broadcaster, in an effort to accommodate formats and leverage content availability, often disrupts the multiplex several time a day switching from one channel line-up to another. Stream characteristics also change on the fly depending on the operation done at broadcaster sites. While those sudden changes are transparent to an ATSC receiver, cable architecture does not accommodate multicasting transparently, possibly impacting service.

Possible impact on services with multicasting.

Depending on broadcaster and site, impacts on cable services and their consequences varies, and can include the following:

Loss of service even though content is present.

Stream characteristic changes disrupt overall equipment performance, starting with the decoder that may need to be retuned to the channel to update stream characteristics. This can be the case when SDTV feeds replace HDTV feeds. In some cases headend equipment may lose the incoming identification information (same program number but different packet ID), preventing automatic restoration even though the content is restored.

Customer satisfaction issues.

If a channel disappears, its session already mapped on the cable plant is still maintained whether the program is there or not. The user tunes to a black screen although it had content earlier, increasing call center activity dramatically. Even worse can be the subscriber who becomes frustrated by the service to the point of cancellation, without ever placing a call. Generally the cable operator is blamed for service loss although it is a consequence of broadcaster multicasting.

Channel line-up confusion.

The switch between SDTV and HDTV format streams brings confusion as far as channel line-up structure and how HDTV streams could be grouped together in logical channel line-up numbering.

SDTV format and HDTV format with upconverted SD content (black bar).

A particular manifestation of channel line-up confusion is when the user sees standard definition 4:3 ratio on a 16:9 ratio television. In one case the user can stretch the image of its television to avoid the black bar caused by SDTV content ratio (see Fig. 4), in the other case the television will not allow it because the feed is already in HDTV format although SDTV content was upconverted. Too much time with black bars on screen also risks image burn-in on the television.

Fig. 4: Example of standard definition stream stretched by television to 16:9 screen.

Satellite and broadcaster alternatives provide a clear indication of what type of feed is broadcasted to avoid this confusion. An alternative for cable is to organize channel line-up per stream format to avoid the confusion, independently from the content when multicasting involves both types of streams on same channels.

Solution to accommodate multicasting in existing cable architecture.

An intelligent re-multiplexing platform capable of real time responsiveness to broadcasters' sudden changes is needed prior to the usual cable session management systems. Strategic positioning of this re-multiplexing can preserve static channel line-ups independently from multicasting events and act as a shield during eventual stream characteristic change.

In response to program loss, a graphic message can be substituted for the program disappearing to offer an indication to the user that a channel will return or is not available, and suggest alternative programming locations. Also, smart session management can redirect streams dynamically to the proper channel number in a line-up whether the format is HD or SD, indicating whether or not television stretching function is enabled.

SUMMARY

Because of the realization of FCC timetables for terrestrial digital broadcasting launch and satellite progress and aggressive marketing, cable is particularly challenged to compete effectively in providing HDTV services. Elements such as constant bit rate encoding, PSIP data tables and real time broadcaster switching between formats are inherently unfriendly to the cable plant.

This paper has shown that an intelligent multiplexing platform can overcome obstacles through HDTV rate shaping; capabilities to combine HDTV and SDTV within the same channels; regenerating PSIP tables for cable in compliance with the NCTA/CEA agreements; and recognizing and accommodating broadcaster format shifts. These techniques enable the cable industry to provide subscribers with a complete and fulfilling HDTV experience. The cable industry can then leverage its own inherent advantages, such as its balanced access to both local and national feeds. Cable operators can be liberated from defensive positioning in HDTV and industry competitiveness can be enhanced.

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