MPEG-2 Digital Program Stream Compatibility: Programming to DCT/Pegasus/Telcos

John Beyler
Home Box Office

Abstract

In the fast-paced world of digital television today, the "universality" of MPEG is not a slam-dunk to get programming from "point A" (the uplink) to "Point-B Telco"; another Point-B (Pegasus headend); another Point-B (DBS redistributor); and , finally, a Point-B "classic cable operator".

This paper describes the issues which must be considered by a programmer desiring to provide digital programming to all users. Issues such as conditional access, statistical multiplexing, system information tables, and video profiles will be discussed.

INTRODUCTION

Until now, universal interoperability has been very easy: NTSC is universally understood and may be scrambled, transmitted, and displayed on everything from Grandma's tube-type TV to hand-held LCD sets. NTSC has provided an easy interface for forty years, with two upgrades along the way for color in the early 1960's, and stereo sound in the mid 1980's.

Easy interoperability has changed with the introduction of digital distribution in the cable industry. Digital delivery platforms start from a common MPEG video compression standard, but quickly turn to proprietary extensions which have challenged cross-platform interoperablity.

HBO began digital distribution of four feeds with such a proprietary system in 1992 using GI DigiCipher-I™ technology. Though this system used many of the components of MPEG-2 video compression, such as block-based processing using the Discrete Cosine Transform (DCT), it predated the MPEG-2 standard, and so used largely proprietary technology.

In December, 1996 HBO completed the replacement of this DC-I distribution system, upgrading its digital network to MPEG-2 video compression with AC-3 audio compression. In the process, HBO's digital distribution focus has changed from a single digital satellite transponder delivering four feeds (for analog redistribution to the home– the DC-I system) to two digital satellite transponders delivering sixteen feeds capable of analog or digital redistribution to the home (the MPEG-2 system).

Analog television has survived forty years (with the two "tweaks" given above) and continues strong today, while the first generation of digital television lasted only four years, and was replaced by MPEG-2 technology last year. And now ATSC Digital TV (DTV - standard and high definition digital television) is rapidly approaching.

DIGITAL CABLE BANDWIDTH

To set the stage for the discussion of interoperablity hurdles for digital systems, here is an overview of digital cable bandwidth, digital satellite technology, and digital delivery architecture.

Cable systems inherited the six MHz channel spacing of broadcast NTSC transmissions, and that same six MHz channel spacing is used for digital cable and broadcast DTV. One six MHz channel can deliver a single analog service, scrambled or in the clear.

One six MHz channel can deliver numerous digital programs, from four to ten, or more, given current compression technology. The motivations for adding digital channels to an analog cable plant are twofold: increase the number of programs available, and increase the picture and sound quality of those programs.

From the analog perspective, delivery capacity or bandwidth is measured in megahertz (frequency domain). In analog, more bandwidth means more quality. For example, broadcast FM radio uses more bandwidth than AM radio to achieve a higher quality.

From the digital perspective, bandwidth is measured in megabits per second (Mb/s), and, in general, more Mb/s means more quality. The building block for digital signals on a six MHz cable system using 64 Quadrature Amplitude Modulation (64 QAM) is 26.97 Mb/s. This payload of 26.97 Mb/s can be allocated among the different program services (audio, video, data) being delivered on that channel.

Digital cable systems (unlike green field DBS platforms which are entirely digital) are using a mixture of analog and new digital capacity. Basic channels with wide distribution will continue on analog channels which can be recovered with a $100 analog converter. Digital services, typically adding premium and PPV programming, will require a more expensive (by three to four times) hybrid analog and digital set-top box.

A distinguishing factor for digital systems is whether they provide broadcast or point-to-point delivery. In the digital broadcast model, all homes within a node receive an identical digital signal package. DBS uses the broadcast approach, and digital MMDS platforms seem to be developing 100% digital broadcast plants for multichannel video. An example of point-to-point systems (which use packet switching architectures) is the Time Warner Full Service Network in Orlando, Florida.

The channel increase by converting analog channels to digital can be calculated as follows. Rebuilt 750 MHz plant can support 116 analog channels. If the top 200 MHz is converted to digital service, the delivery capacity becomes 78 analog channels, and approximately 890 Mb/s for digital services:

33 channels x 26.97 Mb/s
= 890 Mb/s

If you devote, for example, 4.5 Mb/s per program service, 890 Mb/s accommodates about 200 programs. Note that the entire 750 MHz bandwidth does not convert to 6 MHz channels because the entire 750 MHz spectrum is not available for downstream video services (there are gaps for return path, FM radio, and data services).

DIGITAL SATELLITE FORMAT

HBO, along with Showtime, Headend In The Sky (HITS), and TVN, has selected a GI DigiCipher core (conditional access and System Information) for digital distribution. HBO uses two-channel AC-3 audio compression and generic MPEG-2 video compression set for Main Profile at Main Level (MP@ML). The MPEG-2 Main Profile compression is configured to use B-frames and P-frames in a Group Of Pictures of fifteen, where N=15 and M=3. HBO's video compression frame sequence is shown below.

I B B P B B P B B P B B P B B I

HBO's decision to use Main Profile with B-frames was dependent on our affiliates selection of set-top boxes with the additional memory required to decode Main Profile streams.

HBO has chosen a digital multiplex format which delivers two "bundles" of program services on each of two digital transponders. Total digital bandwidth through a satellite transponder is dependent on the choices for modulation format, symbol rate, and error correction rate for the digital multiplex. HBO is using a symbol rate of 29.27 mega symbols per second (Ms/s), where each symbol carries two bits using Quadrature Phase Shift Keying (QPSK). This symbol rate and modulation establish a total digital bandwidth of 58.54 Mb/s through the transponder, which gives an occupied bandwidth that fits within the 36 MHz C-band transponders we use on Galaxy-IR.

The total bandwidth of 58.54 Mb/s is not available for digital television data since some bits must be used for forward error correction (FEC) to compensate for channel errors. Our digital signals use error correction in two main steps: a packet-based Reed-Solomon code which adds sixteen bits of error correction to each 188 bit MPEG packet, and a convolution code rate of 7/8 which adds one error correction bit to each seven data bits. Backing these error correction ratios out of the gross bit rate gives a net information rate of 47.2 Mb/s:

```
29.27 Ms/s x 2 b/s = 58.54 Mb/s
58.54 Mb/s x 188/204 x 7/8 =
        47.20 Mb/s
```

This information rate is further split into two digital multiplexes using an I/Q split modulation (In-phase and Quadrature-phase) to yield 23.6 Mb/s per bundle of HBO digital programs. For reference, DC-I and MPEG-2 transmissions for Ku-band transponders typically deliver an information rate of 26.97 Mb/s.

HBO's digital program distribution uses two transponders on Galaxy-IR with program feeds allocated as shown below in Table 1.

Galaxy-IR Transponder 23
L-band Frequency 990 MHz
Virtual Channel Table 205

I Multiplex	Ch.	Q Multiplex	Ch.
HBO E	101	HBO W	111
HBO 2E	102	HBO 2W	112
HBO 3E	103	HBO 3W	113
MAX E	121	MAX W	131
MAX 2E	122	MAX 2W	132

Galaxy-IR Transponder 18
L-band Frequency 1090 MHz
Virtual Channel Table 206

I Multiplex	Ch.	Q Multiplex	Ch.
HBO M	106	HBOF E	104
HBO 2M	107	HBOF W	114
MAX M	126	future	---
MAX 2M	127	future	---
future	---	future	---

M = Mountain Time Zone HBOF = HBO Family

Table 1. HBO Digital Transponder Loading

More on the (virtual) channel number and the Virtual Channel Table below in the section on System Information.

Other premium programmers and pay-per-view services have converted to the MPEG-2 video/AC-3 audio format or have plans to convert to this format from analog or DC-I transmissions. Including some basic channels, there will be approximately 140 digital feeds in this format available directly from the programmers (including the sixteen given in Table 1 available from HBO).

HITS (a third party packager) is also transmitting digital programming in the GI format, offering packages of program services, along with other value-added services such as set-top management, authorization, and electronic program guide (EPG).

DIGITAL DELIVERY ARCHITECTURE

Figure 1 below gives some details about digital headend architecture, and interface points which may cause problems for interoperablity.

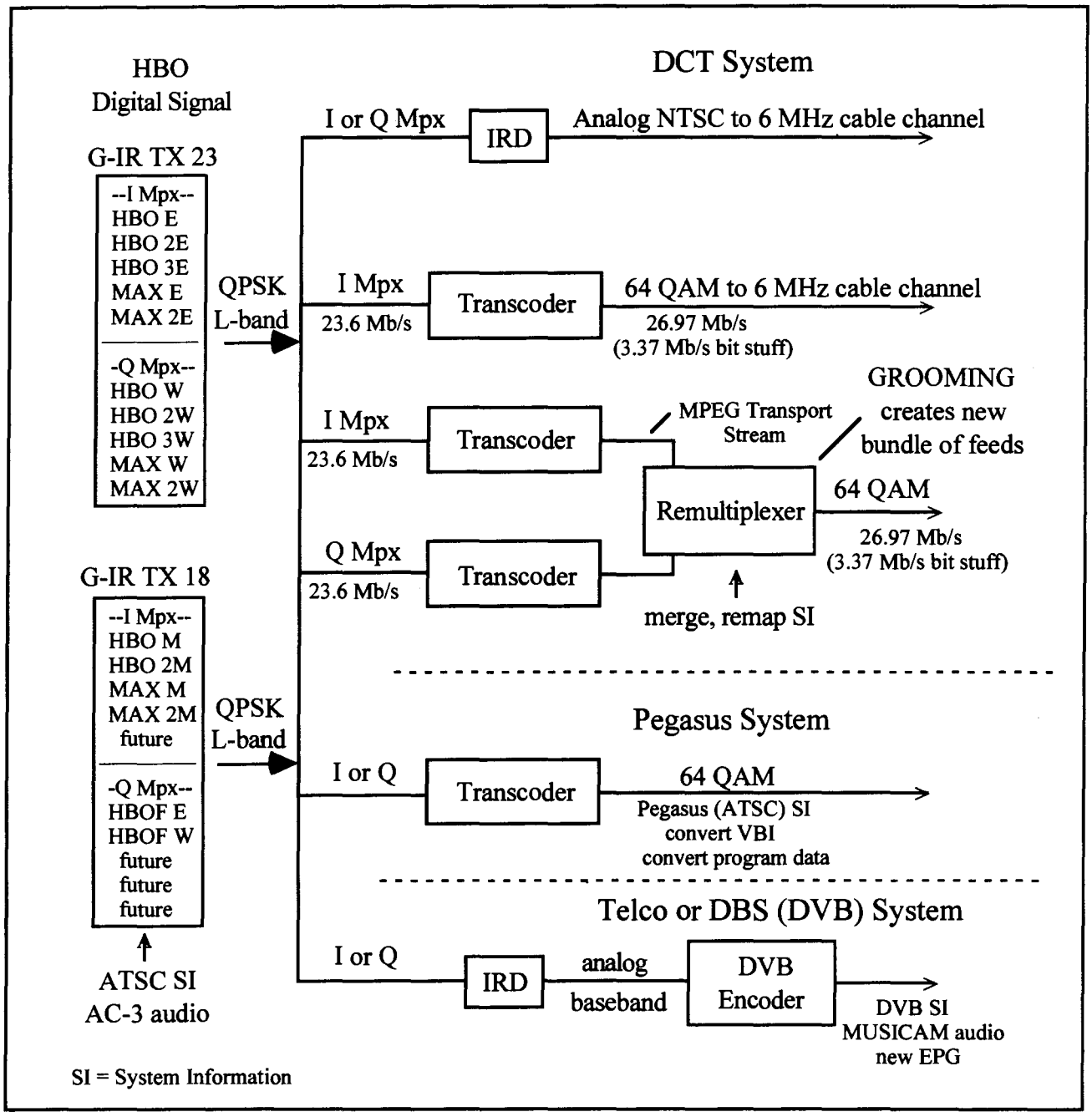

Figure 1. Simplified Digital Headend Architecture

INTEROPERABILITY HURDLES

A primary factor motivating interoperability is avoiding the equipment expense to compress the television signal a second time (up to $80,000 per channel), but there are also quality issues. Programming producers and suppliers would prefer to compress their programming a single time, and retain complete control over the compression algorithms and parameters. One pass through audio/video compression is good. Two passes is not as good, but still viable with cautious selection of compression parameters. Three passes through compression, especially involving encoders with different motion compensation algorithms, may produce excessive compression artifacts.

Digital program multiplexes originated from GI MPEG-2 encoders (whether direct from programmers, PPV operators, or third party packagers) will easily interoperate in a digital headend to send 64 QAM signals downstream to a GI DigiCable™ Consumer Terminal (DCT) set-top box. There are pros and cons involved in acquiring digital programming directly from a programmer or through a third-party packager such as HITS, but the technical interface is straightforward.

It is much more difficult for the digital multiplex to easily translate from the GI MPEG-2/AC-3 format to the Digital Video Broadcasting (DVB) format, used by some domestic platforms. The European DVB Project has produced specifications for digital video systems incorporating MPEG-2 video compression. Two US DBS operators and some telco video systems use DVB technology. The main areas of friction preventing interoperability between these two digital formats are these:

- Audio Compression
- System Information
- Conditional Access

Audio Compression

DVB systems use MPEG MUSICAM (Masking-pattern Universal Subband Integrated Coding And Multiplexing) audio compression. The United States Advanced Television Systems Committee (ATSC) has set a standard for audio compression using AC-3. ATSC digital audio compression is used in DTV, for North American DVD disks, and by the GI MPEG-2 system. AC-3 and MUSICAM use different algorithms and there is no direct translation available for the digital bit streams.

To help eliminate the need to completely reencode video and MUSICAM, HBO has developed a specification and identified a supplier for an AC-3 to MUSICAM converter which translates the audio compression (by way of baseband) while preserving the MPEG-2 compression video packets. This interface requires modification of the System Information to identify MPEG audio, and to correct the Presentation Time Stamps (PTS) and Program Clock References (PCR) to adjust for processing delay. To date, this approach has not been used to interface HBO digital signals to DVB platforms; instead the multiplex is decoded to baseband, and audio and video are then recompressed to the DVB standards. DBS operators who operate a single encoder for millions of subscribers have not indicated a desire to save encoder costs.

System Information

System Information (SI) is the reference data which describes and identifies all the pieces of a digital television signal. The SI consists of a number of tables which are used by MPEG-2 decoders to identify and recover data streams. Some of the main tables used are:

- Carrier Definition Table–gives digital carrier frequency.

- Modulation Mode Table–gives type of modulation used.
- Satellite Definition Table–identifies satellite, if applicable. There are other tables with additional satellite parameters.
- Source Name Table–gives text name of program source.
- Virtual Channel Table–cross reference which coordinates program selection.

The Virtual Channel Table must be downloaded to an MPEG-2 decoder before the decoder can select a virtual channel. HBO uses Virtual Channel Tables (VCT) numbered 205 and 206 for digital transponders on Galaxy-IR, transponders 23 and 18 respectively. This satellite System Information is modified when a digital multiplex is transcoded for cable distribution, for example, the satellite information is not meaningful and the modulation mode would change from QPSK to 64 QAM.

On a digital cable system, a simplified representation of SI tables would appear as shown in Figure 2 below.

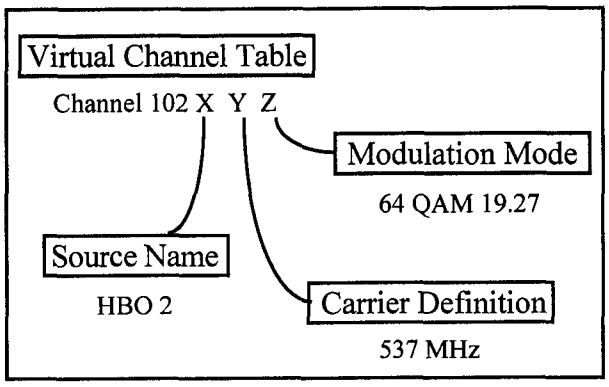

Figure 2. Simplified SI Tables

The System Information must be adjusted at each point the digital multiplex crosses a physical medium boundary; for example: satellite to cable or server to cable.

Harmonization of System Information between ATSC, DVB, and proprietary systems has had limited progress in standards committees. What is essentially a conversion mapping function is frustrated by redundant, reserved, or simply irrelevant data space between the various tables.

Conditional Access

Conditional Access is perhaps the most difficult area of interoperablity for digital systems for a simple reason–network operators do not want their security systems to cooperate. Programmers expect that access and encryption must be segmented in the different layers of a delivery system; different for the satellite and cable plant. Also note that even though the Europeans have developed a common encryption algorithm for DVB systems called Super Scrambling, conditional access remains autonomous.

Other Problem Areas

While audio compression, System Information, and conditional access are perhaps the major areas of interoperability problems, there are other areas of friction preventing a seamless interface.

Carriage of line 21 closed captioning is not just a good idea in the US, "it's the law". The MPEG-2 standard does not dictate the method for handling VBI data, and proprietary techniques have been used to transport captioning information as MPEG private data. The MPEG-2 decoder reconstructs the closed caption data on it's video output.

Different delivery platforms use different rating systems. HBO currently uses a combination of MPAA ratings and content advisories for its programming. These must be mapped to several different scales on different delivery platforms, with the real potential for consumer confusion.

Variable Data Rate encoding for video compression allows digital feeds sharing a multiplex to receive variable allocations of the total available bit rate, depending on their content. This approach can be described as "robbing Peter to pay Paul". An encoder channel with difficult material (high detail, fast motion) can temporarily receive more of the digital bandwidth within a multiplex. This can pose a serious problem for grooming architectures, where independently varying rates from different multiplexes must be combined. HBO currently uses constant data rate video compression to make remultiplexing easier, but is closely monitoring affiliate use of remultiplexing.

Program guide information can be supplied within the digital multiplex of the signals arriving at a headend, in different formats for each delivery platform. This information must be conformed at the headend to a unified format acceptable the set-top, or an alternative approach is to use a third-party guide provider to feed the electronic program guide.

CONCLUSION

In the first days of digital compression the possibility of multiplexing multiple video feeds on a single channel was a real breakthrough in the crowded bandwidth on satellite and wireline systems. There were technical trials and products launched using the MPEG-1 SIF (Source Input File) format, and at that time some felt that "VHS quality" was good enough.

As more digital systems become available, the consumer appetite and expectations for multichannel video are shifting from sheer quantity back towards the quality of viewing experience. Consumers think anything with the "digital" nomenclature must provide a superior quality experience.

A factor which impedes harmonization of digital video is that the market pressure to deploy often overruns the pace of technical committee standardization work. While committees debate the details not covered by MPEG-2, proprietary systems have been deployed. As of December 31, 1996, there were 4.3 million DBS subscribers using digital compression but less than one tenth were receiving "standard" MPEG. Standards committees and vendor cross licensing still must deal with the fact that a deployable cross-platform delivery platform does not exist.

Vendors must cooperate and compromise to achieve interoperability. The hard work is still ahead.

ACKNOWLEDGMENT

The author would like to thank Craig Cuttner, chair of the SCTE Digital Video Standards Working Group #1 on Audio/Video, for his assistance and insight.

REFERENCES

1. System Information for Digital Television, ATSC Standard Doc. A/56, January 3, 1996.

2. Digital Audio Compression Standard (AC-3), ATSC Standard Doc. A/52, December 20, 1995.

3. ETS 300 468 DVB System Information Table.

4. ISO/IEC 13818-3 (MPEG-2 Audio Layer II)

5. EBU Technical Review No. 266, Winter 1995.