MAXIMUM CAPACITY: THE ROLE OF INTELLIGENT EDGE DEVICES IN CABLE NETWORK CONVERGENCE

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Abstract

The ultimate goal of many cable systems operators is the migration to an IP end-to-end delivery model. However, there are many constraints at the HFC level such as existing analog channel assignments, must-carry regulation, legacy set-top box investment, and interface standardization.

Nevertheless, the internal structure of cable systems is evolving rapidly towards a converged IP backbone that carries all content distribution and signaling.

Therefore what is needed is an intelligent edge device that can perform format conversion, protocol translation, and content localization so that the IP backbone can be implemented today, with the ultimate goal of extending IP carriage all the way to the home.

INTRODUCTION

Today cable operators are typically managing four, discrete network protocols over their HFC plant:

- Analog broadcast video
- Digital broadcast video
- On-demand video
- High-speed data and VoIP

The HFC bandwidth allocation for each is statically defined as 6 MHz channels. It is difficult to re-distribute network capacity between services because each has a separate management system, which doesn't 'know' about the other services.

Most cable operators also manage two or more transport networks (regional, and headend-to-hub interconnections). The history of technical development is often the driver for the right choice at the appropriate time, and four different technologies are in common use today:

- AM Supertrunking
- IP over ATM over SONET
- IP (Packet) over SONET
- IP over Gigabit Ethernet

The complexity of protocol conversion and bandwidth adaptation at the edge is significant, but it is now possible to build cost-effective, intelligent edge devices that allow a single transport network and considerable simplification of the HFC network. These developments also support efficient bandwidth management and a graceful migration to a single, converged IP network topology, which will enable rapid deployment of new services without having to invent new operation management systems.

This paper will describe this evolution in detail, and show how flexibility and cost-effective deployment can be achieved at each step of the process. The steps described will cover:

1. Compression of all services to a common coding and transport standard.

2. Transmission of all services over a single, IP-based transport network.
3. Localization of video services to the zone or set-top level using digital program insertion (DPI). Switched Broadcast services may leverage the same infrastructure that is used for localization.
4. Adaptation of services to maintain backward compatibility with legacy devices in customers' homes. (This is especially important for regulatory reasons and to preserve the multi-billion dollar investment the industry has made in MPEG-2 set-tops.)

HEADEND AGGREGATION AND GROOMING

Cable networks have developed over the years by adding new services in an incremental fashion – each new service bringing with it new headend equipment and leveraging existing network transport. As a result of this the cable operator is faced with the challenge of operating multiple different systems, each with its own operational quirks.

For example, when digital services were added, the most cost effective deployment was to modulate and combine the analog and digital channels at the headend and to use existing AM supertrunking to deliver that combined signal to the distribution hubs. Figure 1 illustrates the basic transformations that are done at the headend to allow video feeds to be selectively groomed by the operator into an optimal channel lineup.

As shown in the diagram, all functions that transform the content are done at the master headend. From the master headend, the network uses Amplitude Modulation (AM) Supertrunking to distribute the RF signals to the hubs and ultimately to the viewer's home.

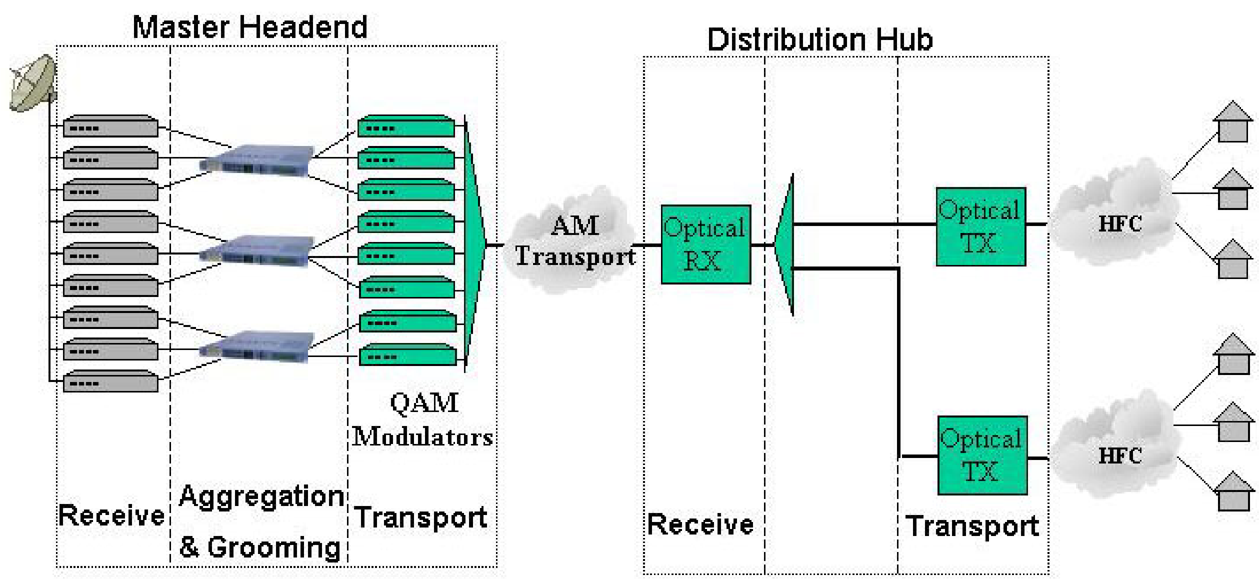

Figure 1: Headend Aggregation and Grooming

In Figure 1, all digital feeds from satellite are fed into a series of groomers, which perform a number of related functions:

1. The feeds are aggregated together, allowing two satellite feeds to be typically combined into a single QAM channel over the cable system.

2. The feeds are groomed to remove any programs that are not required for carriage over the cable system
3. The feeds are re-mapped so that any Packet Identifier conflicts are removed and program map and program association tables built for the consolidated transport stream output.
4. The programs are statistically multiplexed so that the instantaneous bit rate does not exceed the output channel limitation (38.8 Mbps for a 256-QAM channel).

Although this approach has been extremely successful in allowing cable operators to design their own efficient digital channel line-ups, there are some significant disadvantages:

1. The digital line-up is fixed for all parts of the cable system – this may be a problem if different parts of the system are not upgraded to the same capacity.
2. As regional clusters are interconnected, it is possible to push much of the headend functionality back to a regional super-headend.
3. The AM supertrunk is still being used to deliver the digital video channels. As cost-effective digital transport technologies are becoming readily available and are being used to Video On Demand (see later). It is becoming practical to unify all transport over a single, IP transport system.

For these reasons, an all-digital distribution model is rapidly gaining acceptance. As we will see, it is also a foundation for Digital Program Insertion, Video-on-Demand, and Digital Simulcast.

Of course, all digital distribution solves a number of problems. There is adequate capacity available in modern 10 Gbps multi-wavelength transport systems to carry all services over a single backbone. The single biggest issue becomes how to carry feeds over the backbone that are only available in analog format. Until recently it was prohibitively expensive to MPEG encode analog channels, but as encoding costs have come down, and as cable systems have grown larger (so that the cost of encoding an analog channel is spread over a larger subscriber base) this is no longer such an issue.

The other issue, again until recently, was the need to do local commercial insertion into analog channels. This has been solved by the implementation of digital-in-digital insertion systems that operate at the MPEG layer, using a standardized approach called Digital Program Insertion.

DIGITAL PROGRAM INSERTION

The basic principle of Digital Program Insertion (DPI) is that at a given digital cue signal (signaled using the SCTE 035[1] message) an individual output program can be seamlessly spliced from the network feed to a local feed generated by a server. The DPI system has been divided into two main sub-systems; the Ad Server and the Splicer. The two communicate using a set of standard messages according to SCTE 030[2].

After the local commercial is inserted, the program is spliced back into the network feed. To do this successfully, the splicer has to be aware of the MPEG decode buffer model and the structure of the MPEG encoding syntax. In practice the bit rate of the inserted commercial has to be modified to ensure a smooth transition without frame drop or repeat, therefore rate-shaping technology is incorporated into the DPI splicer.

Early deployments of DPI were implemented at the MPEG-2 physical layer using Asynchronous Serial Interface (ASI) interconnections. However, DPI is becoming the first step in the migration to an IP network layer. To achieve this the MPEG-2 transport packets are encapsulated into a UDP flow, which can be carried over an IP network.

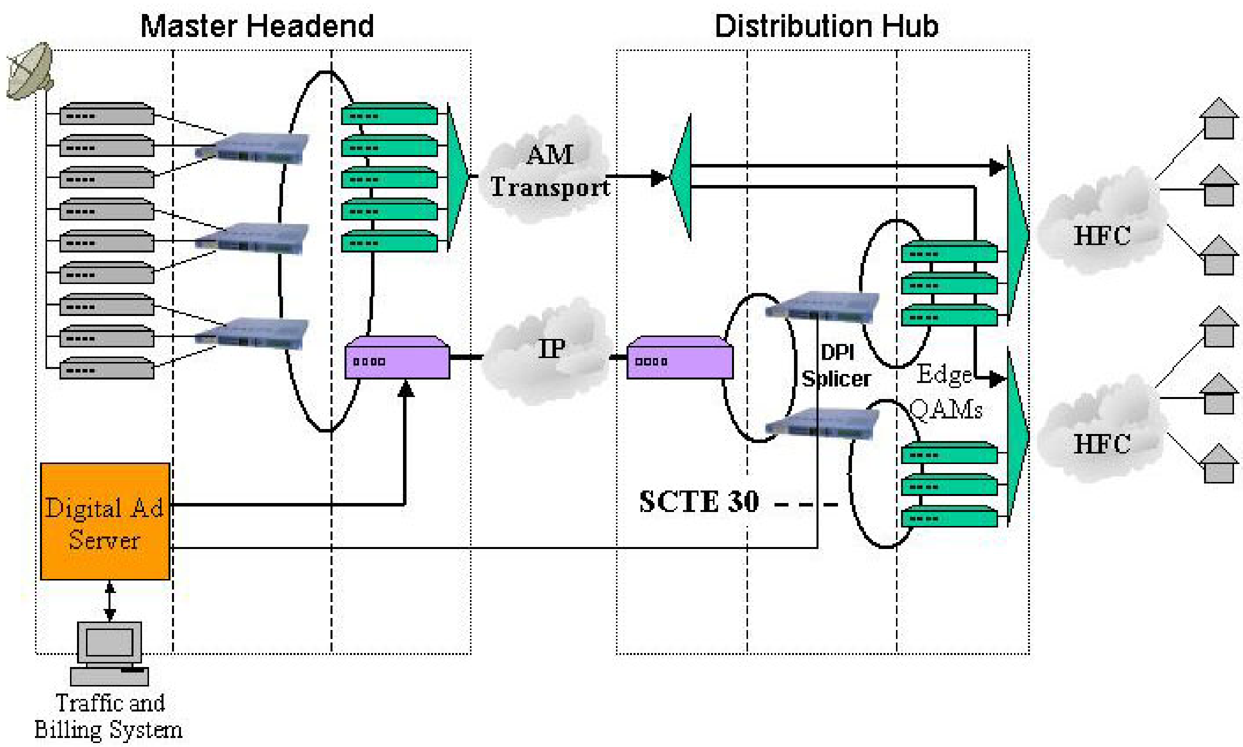

Figure 2: Digital Program Insertion

Figure 2 shows the latest generation of DPI implementation. There are a number of key points:

1. The Digital Ad Server does not have to be co-located with the DPI splicer because they are connected via an IP connection (and not a distance-limited ASI connection).
2. The Digital Ad Server can be centralized at the headend for ease of operations and maintenance.
3. The DPI Splice can be located at the edge of the backbone network at the Distribution Hub. This allows the operator to provide zoned ad insertion to an arbitrarily small serving group area.

DPI is a sophisticated new technology with tremendous flexibility. A good introduction to the DPI standard is available in SCTE 067[3].

VIDEO ON DEMAND

Video-on-Demand is being rolled out aggressively by all major MSOs. The technology has evolved to larger capacity servers with Gigabit Ethernet or 10 Gigabit Ethernet output ports connected over an optical IP transport network to high-density edge-QAM devices.

Figure 3 shows a typical current implementation of VOD. Note that the VOD server is centralized and that the Edge QAMs are distributed to the distribution hub sites. In this diagram a potential future implementation of rate shaping is shown, in which CBR streams are statistically multiplexed before delivery to the edge-QAMs. In the current CBR implementation, 10 streams encoded at 3.75 Mbps per stream can be delivered over a 256-QAM channel. Depending on content, a significant gain of maybe 2-4 streams per QAM can readily be achieved. In some cases this technology may be used to accommodate peak demand without blocking.

The important thing to note is that Figure 3 is identical architecturally to Figure 2. This is a nice property as the same equipment can be easily re-configured between broadcast, DPI, and VOD services. In addition, Switched Digital Broadcast can also be accommodated using this same basic architecture, the additional complexity of Switched Digital Broadcast being extensions to the control plane to allow set-tops to request channels (in the same way that VOD allows a set-top to request sessions).

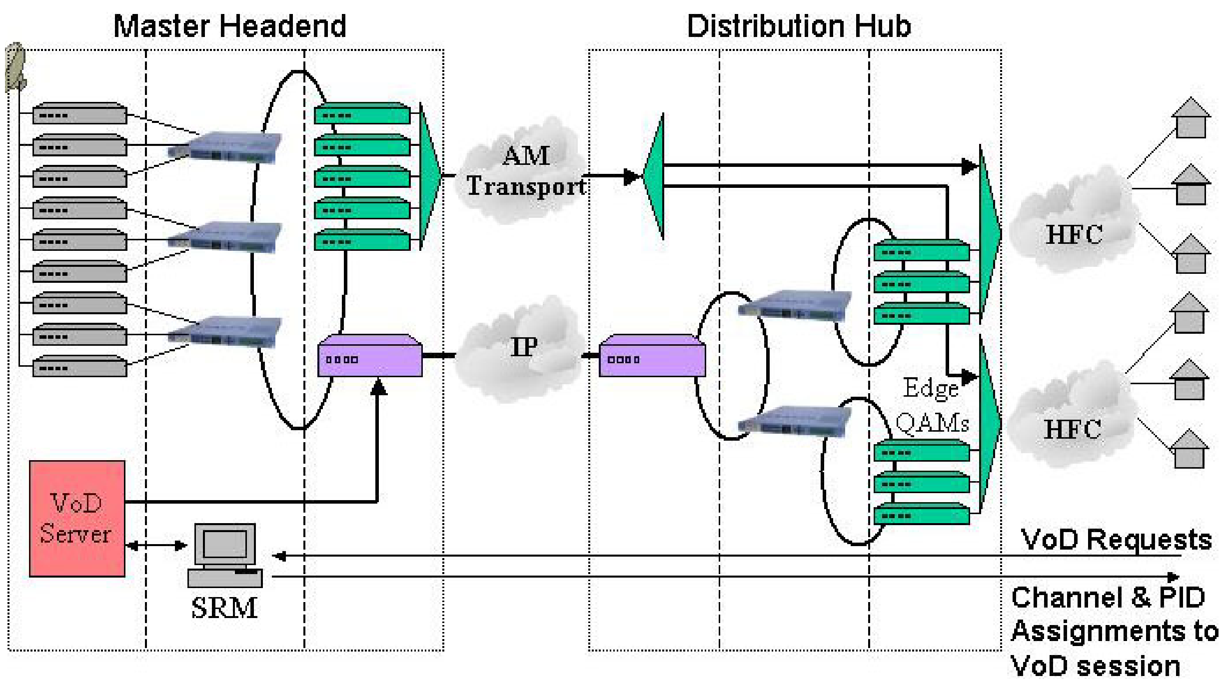

Figure 3: Video-on-Demand

DIGITAL SIMULCAST

Digital Simulcast makes all programming available as part of a digital tier. To do this any analog feeds must be encoded, even off-air signals. Figure 4 shows the processing at the headend to support digital simulcast. Once all of the program feeds are in MPEG-2 format, they can be encapsulated into IP packets for transfer over the converged IP backbone network, which also supports all other connectivity required in the system for on-demand programming, high-speed data, and voice.

When the signals arrive at the distribution hub, an intelligent edge device terminates them and distributes them to the various legacy channels for distribution over the HFC plant as shown in Figure 4.

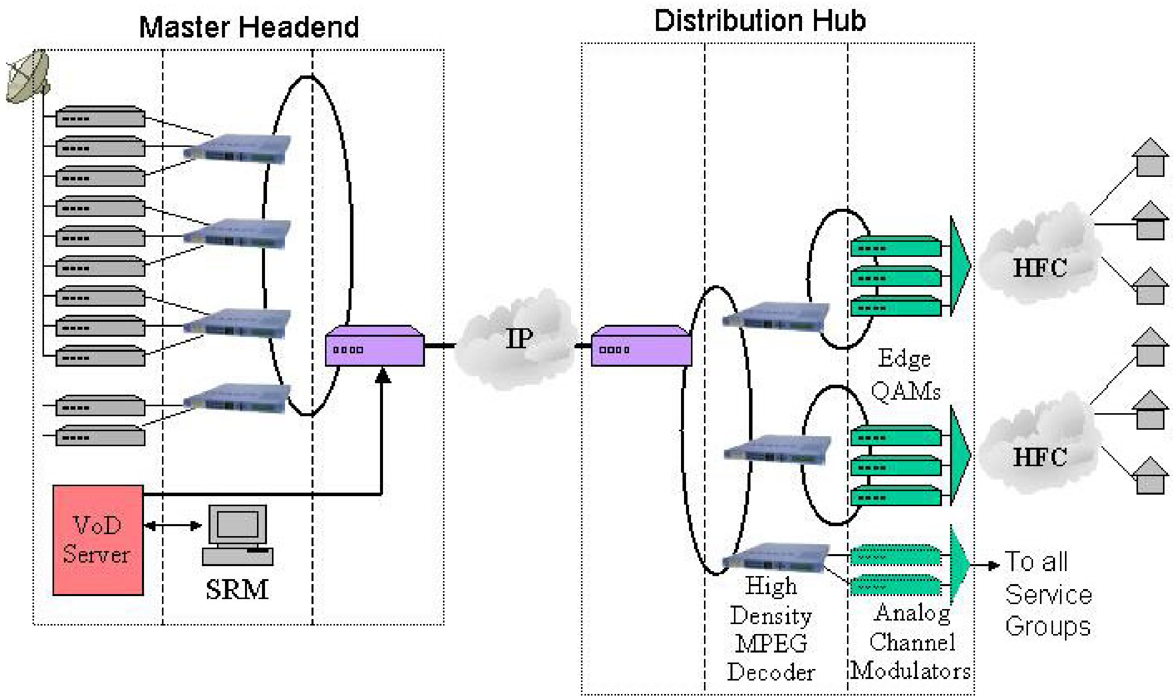

Figure 4: Digital Simulcast

While the operator still has to provide analog channels, an MPEG decoder and analog modulator are required for each channel to convert it back into NTSC format. Over a period of time, the goal of the operator will be to drastically reduce the number of analog channels because they consume so much HFC bandwidth compared with their digital equivalent. As analog channels are removed, more digital channels can be added for broadcast or on-demand viewing. Another advantage is that the DPI splicing in the digital domain is done before conversion back to analog, and so older analog insertion technology can be retired.

At this point in the migration path, we already have achieved complete convergence at the IP backbone level, with all four services – analog video, digital video, video-on-demand, and DOCSIS – running over a single backbone. This allows the operator to reduce operation costs and to operate larger networks more efficiently.

SUMMARY

This paper has illustrated the evolutionary migration path from today's hybrid transport model (using AM supertrunking) to a digital transport model that uses a converged IP backbone for all video, data, and voice transport.

REFERENCES

1. ANSI/SCTE 030 2001 (formerly DVS 380) Digital Program Insertion Splicing API
2. ANSI/SCTE 035 2004 Digital Program Insertion Cueing Message for Cable
3. ANSI/SCTE 67 2002 (formerly DVS 379) Applications Guidelines for SCTE 35 2001

(Available online from the SCTE web site at www.scte.org)