COST VERSUS FLEXIBILITY IN DIGITAL CABLE HEADENDS

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ABSTRACT

Cable Programmers are faced with a multitude of challenges as they move to digital. Maintaining the flexibility of their existing analog systems today must be weighed against the cost of the equipment that it will take to provide that same flexibility in a digital architecture.

An architecture that allows the cable programmer the same flexibility as analog is one that incorporates high definition (HD) and standard definition (SD) digital encoders. In this architecture the program element streams are demultiplexed and switched to allow for commercial insertion. This option however, will be expensive as the cost of decoding and encoding is high today will likely remain so for the foreseeable future.

On the other hand, lower cost options will exist that include processing the incoming programmer and broadcast signals at the transport stream level. This option, however, provides less flexibility than program stream switching. Program streams are not demultiplexed and therefore do not allow seamless insertion of commercial ads. Technologies are becoming available which provide switching between multiple signals at the transport layer.

This paper will compare high cost / high flexibility technology with lower cost / lower flexibility technology for cable headends.

INTRODUCTION

Digital TV promises to change the complexion of television. It will surely change the appearance of the cable headend infrastructure. From simply transmitting a single digital signal to managing a dynamic digital multiplex, cable headends will have many different looks.

The deployment of Digital TV offers the cable operator many options to convert his station to digital. Some cable operators have already begun the transition to digital and are receiving pre-packaged digital programming from services such as Headend In The Sky (HITS). This type of service, while providing many channels tightly packed into a satellite transponder for easy conversion to quadrature amplitude modulated (QAM), is very inflexible for adding advertising or simply subtracting a single service.

Soon, other programmers will also be transmitting their own digital signal, offering an alternative to HITS. Broadcasters likewise, will be transmitting their signals in digital starting this year. Both will transmit some programming in high definition television (HDTV) and other programming in the form of standard definition television (SDTV).

What this all means to the cable operator is that he will ultimately have to find bandwidth to carry these new services while trying to achieve the same flexibility he has today. Competition is driving cable operators to add the new digital services. DBS, Telco and broadcasters transmitting HDTV will force the cable operator to keep up and convert his system to digital. While must-carry for digital services is likely to be hotly debated, if passed, it will further drive bandwidth requirements for the cable operator.

Digital was the promise of virtually unlimited bandwidth for cable. It was believed at least 500 channels could be carried on a single cable. However, with HDTV, the need to add local advertising and carriage of other digital services, the operator must weigh optimizing his bandwidth against the costs to manage that bandwidth.

TRADITIONAL CABLE HEADEND

Compared to the complexity of new digital cable headend architectures, today's analog architecture appears refreshingly simple. Today's analog cable network is built around transmitting just one video channel in one RF channel at a time. Programming is received from typically two sources; cable programmers over satellite and broadcasters over-the-air or via a direct fiber link. Figure 1 illustrates this.

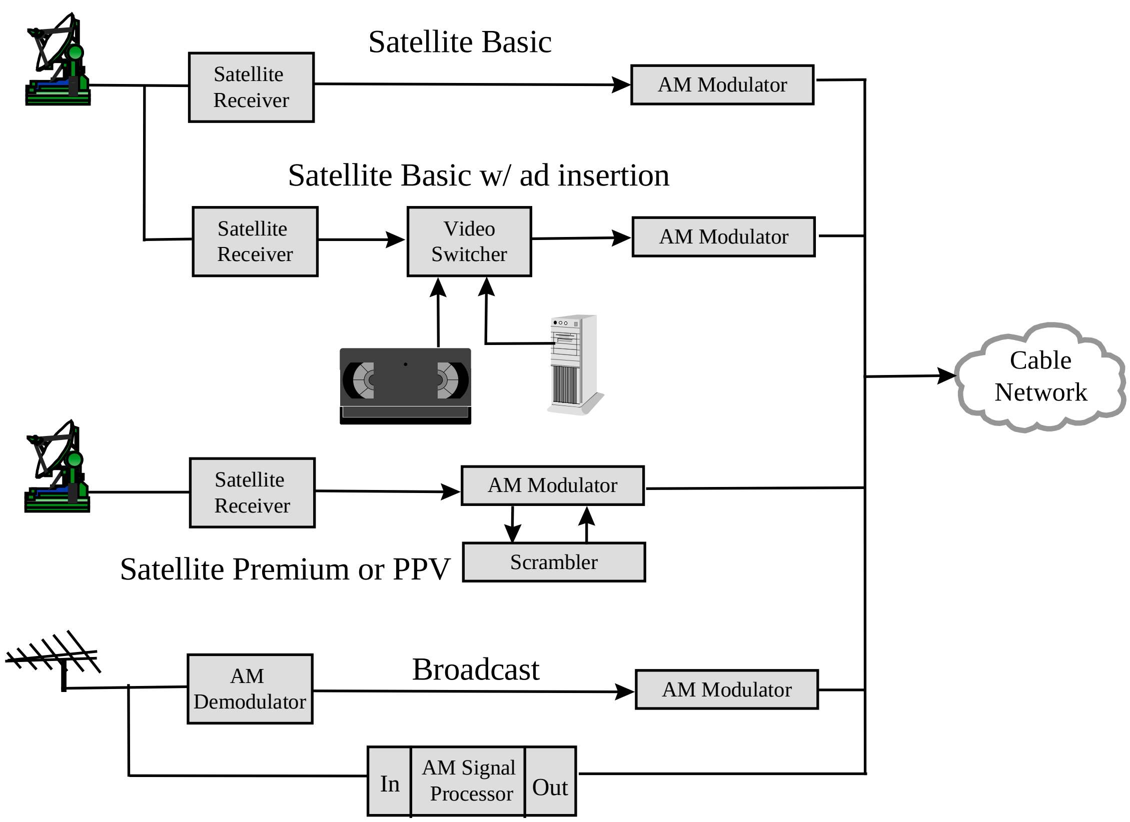

Figure 1. Traditional Headend

Cable programming takes one of several forms. It is either a basic, premium, or pay-per-view (PPV) service. If it is a basic service, then it will either allow local ad insertion or be passed straight through over cable. Premium services are scrambled or secured passively (traps) while providing no ad insertion opportunities. PPV is always scrambled and authorized addressably through a set top box. No advertisements are allowed on the PPV channel except on video barker channels.

Broadcast channels are received using a signal processor. A signal processor receives the broadcast signal on frequency, cleans up the out-of-band noise and amplifies it to approximately 60 dBmV. The processor either converts it to a different frequency for cable distribution or keeps it on-channel. Ad insertion is not allowed on over-the-air broadcast channels.

Ad insertion, which accounts for an increasing portion of cable systems' revenue today, is inserted on basic channels with available local spots. Ad insertion has already gone the way of digital in many headends. Ads are queued on a server and played out at the appropriate time and decoded back to analog before being inserted into the analog channel.

In analog, cable headends are simple and flexible. Digital cable, on the other hand, now limits the operator's operational flexibility and the insertion of advertisements into local spots.

DIGITAL CABLE CHALLENGES

Digital Cable presents several challenges to the operator. The first is where does the operator find the bandwidth to carry all these new digital HDTV and SDTV programs? The second challenge is how can the operator optimize his bandwidth to extract every bit possible? The final challenge is how does the operator achieve the same flexibility he has today in an analog system?

Pipe Analysis

If we consider the multiple transmission formats or "digital pipes" that affect cable we see that the inbound and outbound data rates are not the same. Because digital modulation formats used by satellite, broadcast and cable are all different, the information rates do not equal. Satellite transmission uses QPSK modulation over either 36MHz or 27 MHz transponders. Different transponder bandwidths are used in an attempt to optimize cable's information rates, however, this is an inefficient use of the transponder if the transponders' bandwidth is not optimized. Digital broadcast transmission will use 8VSB modulation which provides an information rate of 19.39Mb/s. Cable's outbound digital pipes will use either 64 or 256 QAM.

Different spectrum bandwidths and modulation efficiencies result in digital cable bandwidths that will not be easily optimized. Consider Table 1. Cable programmers using satellite distribution must decide how they transmit their service to the cable operator. They must consider the number of services they are trying to deliver versus the transponder spectrum bandwidth available. For example, if the programmer is planning to deliver 10 channels each at 4.0 Mb/s, then he will overrun the cable operator's capability to transmit a 40Mb/s multiplex transport stream. As a result, operators cannot carry a 40Mb/s transport stream because it does not have a large enough out-bound pipe. Therefore, the operator will need to "break up" the multiplex.

	Inbound		Outbound	
Pipe	**8VSB**	**QPSK**	**64QAM**	**256QAM**
Broadcast	19.39Mb	-	-	-
Satellite (36MHz @-40dB)	-	42.74Mb	-	-
Satellite (23MHz @-40dB)	-	27.27Mb	-	-
Cable	-	-	27Mb	38.81Mb

Table 1 Digital Pipes' Information Rates

Broadcasters, on the other hand, will be using 8VSB which provides a maximum of 19.39 Mb/s information rate at the full transport level. Broadcasters have said they will use this spectrum to transmit either HD or SD programs. Only one HD program at the highest scan rate of 1920 X 1080I can fit into the broadcast transport stream. Whereas, four or five SD programs are possible in the same bandwidth. In either case 19.39Mb/s does not fill-up the out-bound pipe creating wasted bandwidth.

Digital Pass-Through

Operators must decide how they will convert their digital signals to digital cable signals. The lowest cost method is called pass-through. Cable operators will want to pass-through the signals received from satellite and broadcasters because only a minimum amount of equipment is required. Programming from satellite can be received by an integrated receiver decoder capable of decoding all programs, simultaneously. The output of this multi-decoder will be an over-the-air transport stream. The transport stream will have local conditional access added and then be modulated on the cable by a QAM modulator.

Programming from broadcasters will be received either off-air or from a dedicated link from the broadcaster. If the signal is received off-air, then it will be received by an 8VSB demodulator capable of providing the transport stream from the broadcast signal. This output will then be remodulated by QAM modulators. Conditional access will not be needed for the broadcast signal.

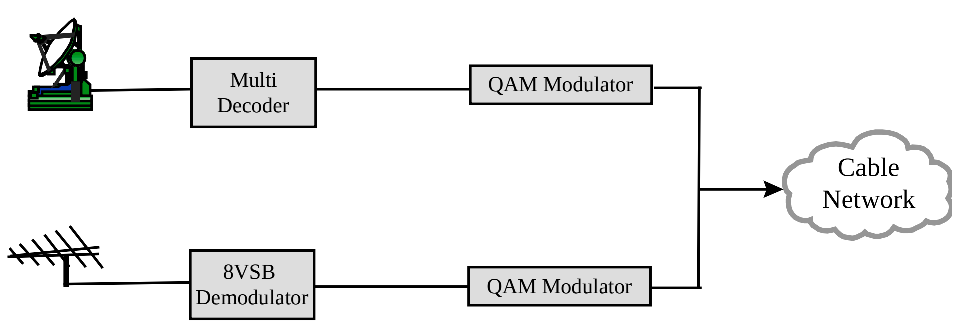

Figure 1. Pass-through

Bandwidth Analysis

So, why is simply passing-through the signals a big problem? Less equipment is needed and therefore it must cost less. The cable operator can use the digital equivalent of satellite receivers, modulators, and signal processors to convert satellite and broadcast signals to the cable format. Unfortunately, the problem is that digital compression has changed all the rules. An analog video signal is the same whether it is satellite, broadcast, or cable. In digital, the same video signal can be 19Mb/s of HD, 5Mb/s of high quality SD, or 2Mb/s of low quality SD, depending solely on the content originator.

What this means then is that depending on the content data rate and whether it is received from satellite or broadcast, the cable operator may be sacrificing more bits than is necessary. Table 2 illustrates a hypothetical cable system's bandwidth environment. The incoming broadcast and programmer services have different numbers of program streams. The cable operator's outbound pipe can be either 64 or 256 QAM and is compared to the satellite and broadcast inbound pipes. What becomes noticeable is that in a pass-through implementation the input and output pipes are not optimized. Satellite delivered services, unless tweaked down in data rates, overruns the output pipes. Broadcast signals, on the other hand, underrun the output pipes. In the case of broadcast programming the wasted bits begin to add up to real bandwidth.

			Unused Bandwidth	
Service	**PES**	**Inbound Bandwidth**	**64QAM**	**256QAM**
CBS	1	19.39Mb	7.61Mb	19.42Mb
ABC	1	19.39Mb	7.61Mb	19.42Mb
NBC	1	19.39Mb	7.61Mb	19.42Mb
FOX	4	19.39Mb	7.61Mb	19.42Mb
HBO	2	27.27Mb	-.3Mb	11.54Mb
Discovery	3	27.27Mb	-.3Mb	11.54Mb
Turner	2	42.51Mb	-15.54Mb	-3.7Mb
MSG	2	42.51Mb	-15.54Mb	-3.7Mb

Table 2

For example, the information rate difference between a single 8VSB broadcast signal and one 64QAM cable signal is 7.61Mb. This is enough bandwidth to carry at least two program streams of reasonable quality video and even more with lesser quality. At 256QAM the difference is more dramatic. As cable systems begin to carry digital signals operators cannot afford to waste bandwidth and must examine ways to recover this unused bandwidth.

Grooming

One technique that allows the operator to overcome the bandwidth inefficiencies is "grooming." Grooming allows an operator to receive an array of compressed program streams from different sources and multiplex them in his own unique way.

Of course, grooming requires more equipment to implement and therefore is more expensive. However, operators are likely to reach a point when delivery of digital programming dominates its bandwidth and that bandwidth becomes scarce. When this happens, the operator will need a way to squeeze out every possible bit for more services whether it be video, audio or data. Figure 2 illustrates how to accomplish grooming.

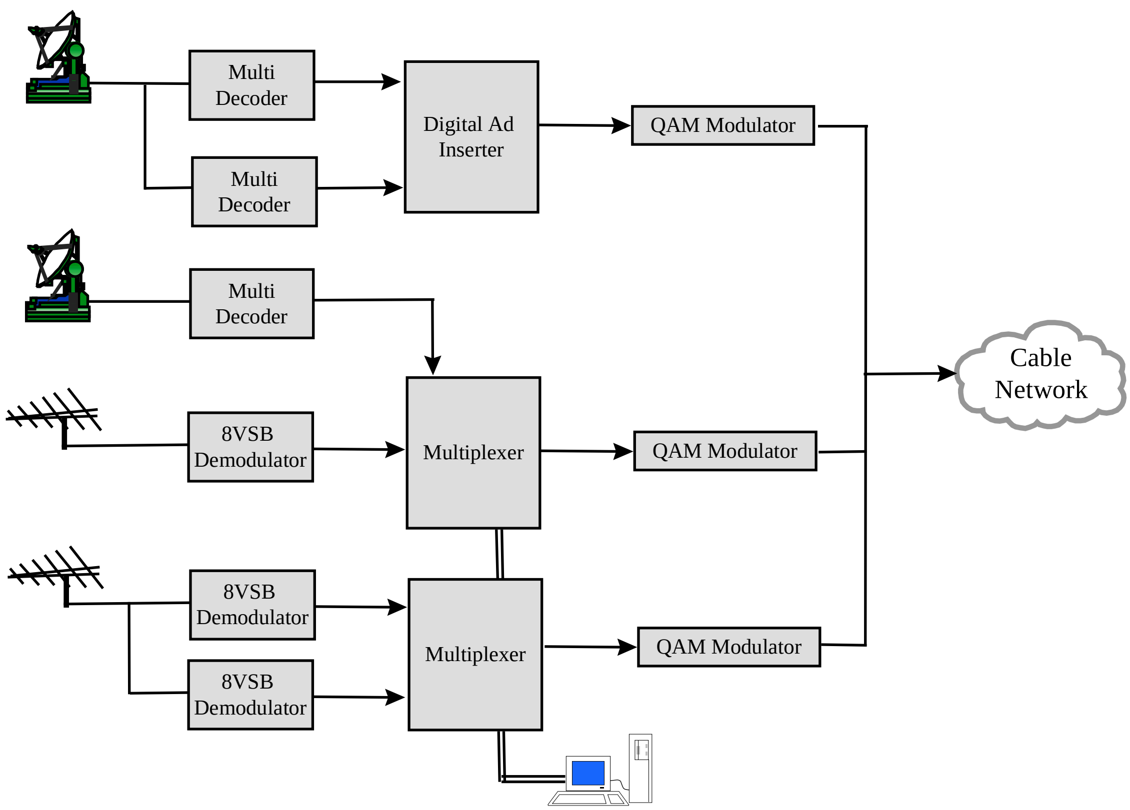

Figure 2. Grooming w/ Digital Ad Insertion

With the use of multiplexers, operators can manage the bandwidth of their digital network. Multiplexers allow "cherry picking" program streams in a way to maximize the data in the transport stream. Program streams that are not desired can be easily deleted. Transport streams that do not fill up the "cable pipe" can be combined with other transport streams. Where there is bandwidth left over, data can be inserted into the transport stream to provide for digital set top boxes or TV applications.

Ad insertion will be accomplished using a digital ad inserter. Compressed program streams from the IRD will be input into the digital ad inserter. Ads will have been already compressed and queued up on a server. At the appropriate time ads will be switched into the transport stream while the program stream is temporarily deleted. At the end of the ad, it will be switched from the transport stream and the program stream re-inserted. Switching at the program element stream (PES) layer is called splicing.

Splicing can be non-seamless or seamless. Non-seamless splicing means there is a momentary visible artifact or glitch in the picture as the IRD needs an I-frame from the new program stream to lock-up. Seamless switching means the inserter knows where the I-frames are in both streams, buffers up any difference, and switches when they are equal or close to it. Splicing is the optimum way to switch in the compressed domain, however, it requires more sophisticated multiplexing equipment and pointers in the MPEG streams to identify splice points. Today, splicing is in early development but will eventually be commonplace as the demand for seamless switching increases.

Conclusion

Digital, while it offers cable operators increased channel capacity, also threatens to consume much more bandwidth than it needs. Because the size of the pipes are not naturally equal, the operator must take measures to minimize bandwidth waste and protect his assets.

The operator's challenge is recovering wasted bandwidth and then adding or combining other services. Pass-through offers the lowest cost alternative to trans-modulate digital signals for broadcasters and programmers, but does not allow the operator to recover unused bandwidth. To overcome the limitation of pass-through, operators will employ multiplexers with grooming capabilities to manage systems that will add, drop, and combine program element streams and optimize the digital pipe.

Initially, switching between digital programs will be crude and cause minor impairments in the video. As we employ tricks like fade-outs and fade-ins we can minimize glitches. Eventually, techniques such as splicing will make program switching and ad insertion seamless in the digital domain.

In the past, a cable system's infrastructure has been the cable operator's most important asset. In the future, bandwidth will be the most important asset in a digital cable system. Tools such as multiplexing systems will help cable operators manage this asset more effectively and overcome bandwidth inefficiencies created by new demands placed on that bandwidth.