SCALABLE BROADBAND ARCHITECTURES

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Abstract

More choice is a proven winner in cable television. In recent years, cable operators have made strides in providing more channels by extending the useful frequency range, and through digital compression. Powerful competitors such as direct broadcast and digital subscriber line service to the Internet continue to push for still more choice.

How can the cable operator continue to provide more choice to the customer while maximizing the returns on their investment in existing plant? One compelling way is by taking a page out of the data communications networking book and using switching technology to deliver the right mixture of services to each of the fiber nodes of their network.

This paper explores the way that switching technology allows the introduction of advanced services and thousands of new television channels.

THE TWO TIER ARCHITECTURE

Headends and Hubs

Many cable systems consist of a central headend, in which satellite and off-air broadcasts are received, and hub sites from which fibers are distributed to neighborhood nodes.

Figure 1 shows this arrangement. The terminology 'Service Groups' is used to refer to a single fiber node or a collection of fiber nodes that serve a group of customers. Some operators refer to the Service Group as a 'Forward Carrier Path.'

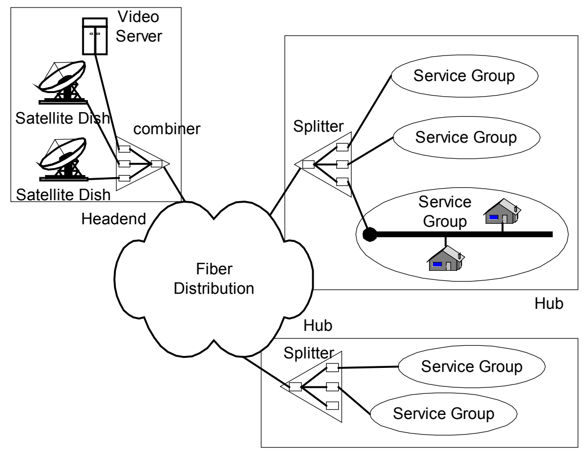

Figure 1 - Headend and Passive Hub Sites

This system works well for traditional broadcast video distribution as the signal can be split for distribution over the most economical means, optical fiber, to different neighborhoods and then finally delivered over coaxial cable to the home. Several variations of this type of network exist that increase the resilience of the fiber distribution against single component failure.

Expanding content availability strains the traditional passive broadcast model. In the same way that Ethernet Switching has increased the effective capacity of data networks, the capacity of broadband networks can be increased by replacing passive splitting elements with switching elements. This change allows the operator to customize the services offered and make maximum use of what proves to be the most limited, and costly, element of the system: the fiber-to-coax conversion and the final run of coax to the home.

Figure 2 shows the replacement of passive splitters with switching elements. With the introduction of multimedia switching, the ability to provide locally inserted services, and more choice, becomes possible.

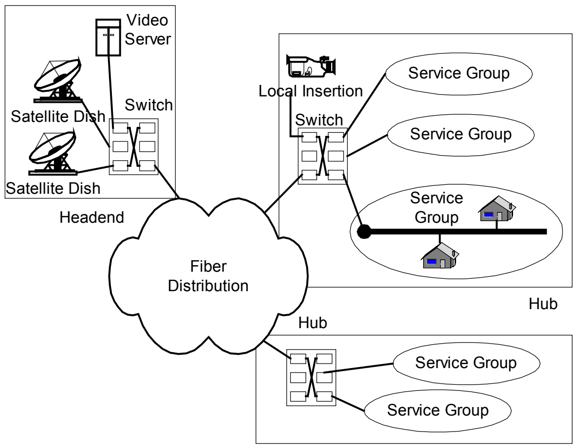

Figure 2 - Headend and Active Hub Sites

Tier One – The Headend

The headend contains facilities that benefit from centralization. Satellite reception, large capacity video servers and access to the Internet backbone are best located at this point in the network. The first tier of switching at this point allows customization of the services sent to each hub.

For smaller communities, direct switching from the headend to fiber nodes serving neighborhoods provides enough capacity per subscriber to support each subscriber adequately.

Tier Two - The Hub

A hub generally serves a geographic area. If sufficient demand for geographic diversity exists, the hub is the ideal site for the introduction of localized services through switching, for example a Video-on-Demand server for “Top 10” hits or culturally targeted programming. This not only provides more choice to the subscriber, but also has been shown to drive higher buy rates.

Fiber distribution to the hub can be implemented in two ways, with pre-bundled multi-program transport multiplexes or as large collection of single-program streams. If the first option is chosen the complexity at the headend is increased but the job of the switch at the hub is simplified, conversely, the opposite is true of the later option.

Switching at the hub provides the next great expansion in available bandwidth. This bandwidth can be utilized in simple ways, for example by providing different channel line-ups for different areas, insertion of ATVEF data, other interactive TV content or for narrowcast services such as Video-on-Demand. It can also be used in more innovative ways, described later in this paper.

Using Service Groups to Extend Bandwidth

The Service Group represents a collection of homes that share bandwidth. The second tier switching element shown in Figure 2 customizes program offerings and data delivered to each service group so that only the services required in that group occupy bandwidth.

This process is analogous to the actions of an Ethernet switch that improves performance on each leg of the network by switching only the packets required by that leg of the network.

Although not highlighted in this paper the devices that enable switching to the appropriate service group also enable insertion of services customized to that group, such as regionalized ad-insertion, VoD and in-band data delivery.

Implementation

Moving from today’s passive transmission systems to switched systems will be an evolutionary process. As switching progresses deeper and deeper into the network, consideration must be given to existing network infrastructure, investment in set-top boxes and the scalability of switching devices. Fortunately, like the ever-growing branches of a fractal, switching systems can grow gradually to meet these needs.

To think of this another way – deployment of distributed switching in the network can be performed incrementally, the capital costs of such a deployment therefore rise in small steps. In contrast, deployment of central office based services requires a single giant step that represents a much larger risk.

Figure 3 represents current equipment arrangements at a digital headend. Various services are combined prior to distribution to fiber nodes.

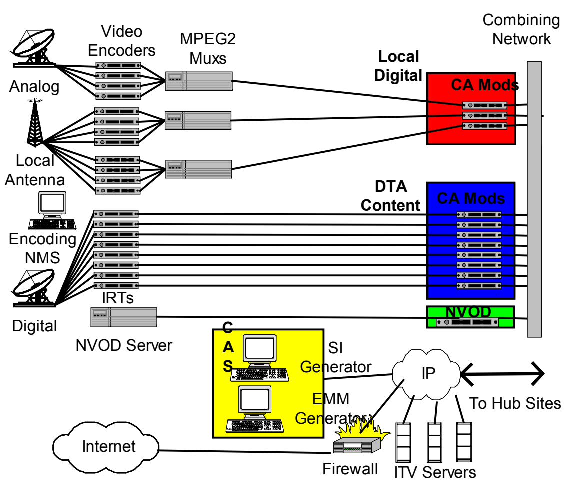

Figure 3 – Current Digital Headend

This picture changes when a switching device can prepare unique variations of services for each Service Group. This is illustrated in Figure 4.

Finally, when distribution of processing power is required at the hub site the picture is again transformed to Figure 5.

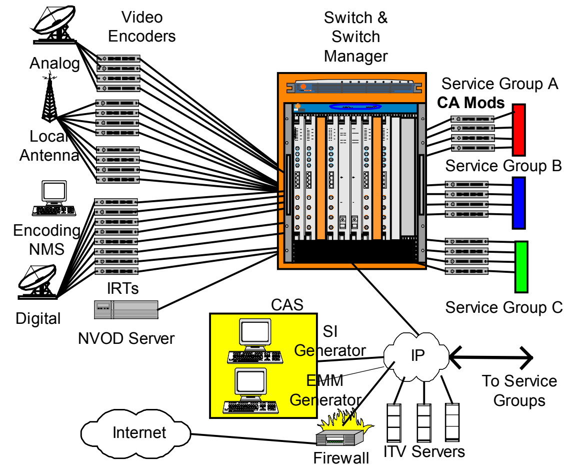

Figure 4 – Switching to Service Groups

Distribution of processing capacity to the hub:

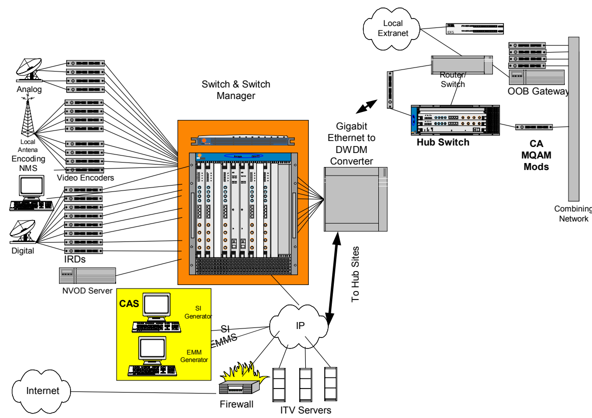

Figure 5 – Switching at the Hub

Switching Technology

Several choices of switching technology are available for use at tier 1 or tier 2. These include:

1. ATM switching using AAL5 encapsulation.
2. Ethernet switching using one of several physical Ethernet interfaces (e.g. 100baseT, gigabit optical.)
3. MPEG-2 transport switching with industry standard DHEI and ASI interfaces.
4. SONET.

SONET and ATM switching are widely used in telephony and in some existing cable plant. However, switch costs and flexibility will increasingly favor gigabit Ethernet in coming years for fiber distribution. Switching of synchronous MPEG-2 transport and interfaces to existing MPEG-2 equipment (such as IRTs) play an important role in the headend and hub, such interfaces must continue to be supported.

In addition to the star topology described in Figure 2, cable networks have been implemented using a ring connecting each hub. The ring somewhat reduces the need to switch data at tier 1. It is, however, still beneficial to combine channels into statistical multiplexes at this level, perhaps even carrying certain channels more than once in order to reduce the switching load at the hub. Clearly this is not theoretically needed but is an example of an optimization that can be performed for economical deployment.

Video Processing

Unlike many data streams, audio and video information cannot be flow controlled to suit the recipient of the data. Producing a mixture of channels for each neighborhood can be made significantly more economical if video processing techniques are used in delivering the content. Producing a statistical multiplex of variable bit-rate video is a form of flow control that improves the usage of a transmission channel.

NICHE PROGRAMMING

Because the final stretch of cable to the home has a finite capacity the operator has been placed in the often-awkward position of choosing among available sources the television channels that will best serve their community. As such, individual subscriber choice is limited because of the need to consider the whole community or comply with must-carry regulations. Expanding the numbers of channels available and providing the flexibility to switch only those requested to the neighborhood enables the operator to be one of the 'good guys' with little risk of long term commitment of transmission network bandwidth.

Broadcast-on-Demand Switching

Broadcast-on-Demand, the ability to join a channel or program in-progress, and only burden the local cable segment with the cost of carriage for that channel, is made possible with three technologies:

1. Economical high-speed multimedia switching that directs the needed channel to the correct branch of the transmission network. Economical switching necessitates the use of statistical multiplexing and video rate-shaping.
2. Multicasting to enable a single copy of a channel to be shared on single branch of the transmission network.
3. User directed channel selection. This could be dynamic, e.g. the set-top box signals channel changes, or less dynamic, e.g. conventional customer subscription.

In order to implement Broadcast-on-Demand the set-top box signals the desired channel upstream to a Switch Manager. The Switch Manager uses information about the desired channel and the user's Service Group to signal the switch at the headend (tier 1) for the desired channel to be transmitted to the appropriate hub. The Switch Manager then signals the switch at the hub (tier 2) to transmit the channel to the user's service group. Subsequently the set-top box tunes to the appropriate frequency and program.

If the desired channel is already being switched to the hub or the appropriate service group, no additional switching actions are required and the set-top can join a multicast of the channel. The Switch Manager maintains a count of users for the channel so that it can remove the channel from a specific service group when all its users have dropped out.

Channel Surfing Switched Programming

Ideally the user should be able to surf through all available programming in the manner to which they have grown accustomed since the introduction of the TV remote control. Digital television has already affected the users ability to do this due to the long acquisition time required to capture the first frame of a program. The user has responded by flipping through channels, reading only the information bar describing the programming and finally alighting on a program of interest. Given enough transaction processing capacity a Broadcast-on-Demand solution need only add modestly to this wait for the first frame of video to appear.

Several related options exist that the public may embrace; each of these is enabled by switching:

1. Channel choice through the Electronic Program Guide.
2. A surfing channel that cycles quickly through available channels.
3. A surfing mosaic, giving the user instant access to several channels simultaneously.
4. Conventional channel surfing

The Electronic Program Guide has long been a focus for choosing available programs. Some users have embraced the guide, but others continue to click-click through programs because it is easier than using the guide, and possibly because of the dullness of seeing the choices printed.

A surfing channel has the advantage of eliminating the acquisition time between digital channels – a disadvantage is that most surfers click quite quickly.

A surfing mosaic again eliminates the acquisition time between digital channels. Several channels are displayed in a matrix so that all are simultaneously visible. An additional enhancement would allow the user to surf the sound on each channel as it can be processed more quickly.

Finally, the same model the user currently uses – simply pausing on a channel – note: when the user pauses on this channel the channel change at the tier 2 switch occurs.

Video-on-Demand

It should be noted that Video-on-Demand programming supplied by file servers shared many of the same switching problems that are solved by switching for Broadcast-on-Demand. It would be useful if the Broadcast- and Video-on-Demand interfaces were shared. This would present the customer with a full range of options in a unified manner and allow them to choose among them.

Advanced Services

Using the switched architecture described above more advanced services such as in-band data and ad-insertion as possible. These can be integrated with broadcast content. The localization of such switching allows powerful opportunities for targeting.

Network Usage

Carrying the right mixture of programming to each neighborhood implies keeping track of the channels in use, adding to them when requested and removing them when no-one is watching. The aggregate time that a niche program is in use is surely a useful statistic for the transmission network planner and network advertiser.

Conclusion

The segmentation of the broadcast cable television network into units that serve a smaller group of customers makes possible an increase in the number and quality of services delivered. Switching devices enable the appropriate mixture of services to be tailored to each segment of the network, for economical deployment these switches need to include features that accommodate legacy equipment such as existing MPEG-2 set-top boxes and multi-QAM modulators. Extending switching concepts to broadcast services extends these advantages, with potential to remove bounds on what content can be offered to subscribers and to expand functionality.

BigBand Networks has implemented a Broadband Multimedia-Service Router, that operates using a hybrid Ethernet/ IP / MPEG 2 transport technology. Powerful video processing allows efficient use of standard MPEG-2 transport streams. The switching unit is complemented by a Service Manager, using a variety of protocols, including industry standards such as DSM-CC.

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