On-Demand Network Transport Architecture

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Abstract

The paper explores the architectural requirements to support an on-demand interactive digital network within the hierarchy of a hybrid fiber coax network. A traditional entertainment network is fundamentally a broadcast network. As new services, such as telephony, high speed modems and interactive televisions are introduced, can the same physical transport support them? What are the differences in their requirements? What are the behavioral differences of a broadcast network versus an on-demand network? The paper reviews the current distribution hub-master hub based HFC network and discusses available options to accommodate new digital switched services.

INTRODUCTION

All HFC networks are not created equal. Time Warner Cable's Master Headend, Transport Hub, Distribution Hub architectures were designed to accommodate various new businesses proposed by the industry. These new services can be categorized into three businesses; Entertainment, PC Data, and Telephony. They all have specific requirements that necessitate different implementation strategies on the Hybrid Fiber Coaxial (HFC) network.

Entertainment services require a high bandwidth, constant bit rate, highly asymmetrical communication path to deliver MPEG-2 programs to the television. PC data requires a high bandwidth, bursty, variable bit rate, communication path to delivery data to the personal computer. Telephony requires a low bandwidth, symmetrical, isochronous communication path for delivery of voice to the telephone. Equipment developed to deliver each of these services is optimized to satisfy their delivery requirements. All must be layered upon the existing HFC plant that has been optimized for the delivery of broadcast analog television channels. This paper will discuss how the on-demand interactive entertainment signals are added to an existing HFC plant.

GOALS

The traditional cable television system has been a broadcast network. The headend was the origination point for all services delivered throughout system. All of the services flowed from this point to all subscribers. Occasionally there maybe some local signals that were inserted at different areas to fulfill franchise requirements, but for the most part all customers receive that same channels. In addition, most of the services delivered were analog. Lately, digital services such as video game download channels, and digital music services have been deployed, but they remain as broadcast service. The primary delivery mechanism for these services has been amplitude modulated fiber-optic links and analog coaxial cables optimized for delivery of broadcast services.

On-demand interactive entertainment services bring major changes to this method of delivery. No longer can you deliver the same channel mix to all the customers since a customer in an area may request a specific program at any time. An on-demand interactive entertainment system must be designed to handle these on-demand requests simultaneously. The number of simultaneous requests that the network can service is referred to as the 'peak load' of the network.

Designing for peak load is common for telephone companies, and they have a wealth of historical data to base their design upon. For an on-demand interactive network, peak loading behavior is not very well known. No one really knows how many customers will be requesting the new release of a blockbuster hit the first Saturday night it is available on the network, or what happens to a movie's demand over time. The network must be designed to be able to deal with a variety of situations that may require that more channels be available in one area than another. This focusing or narrowcasting of channels is a new concept that cable television engineers must understand to be able to design cost effective on-demand networks.

It is imperative that an on-demand interactive network be integrated into our existing broadcast based system, if only to preserve the investment to date. On-demand interactive services by nature are sent to a specific customer in a specific area. The network must now support the routing of a channel to an area. But, only a portion of the available channels are on-demand, the majority of channels are still broadcast to all customers. The introduction of new on-demand interactive entertainment services must consider the existing infrastructure and to work harmoniously with it.

New services must be introduced incrementally and cost effectively. Even though we all believe that on-demand interactive entertainment services will be a great business someday, it would not be prudent to design or build a network to handle those anticipated peak loads today. The network must be designed so it can grow as the demand for services increases.

In review, the goals of an on-demand interactive entertainment system are:

1.Capability of handling peak loads.

2.Ability to grow as demand increases (scalability).

3.Fit into existing broadcast infrastructure.

4.Cost effective deployment.

Let review the components necessary to support an on-demand interactive entertainment system and TWC's Hybrid Fiber Coaxial design to understand how to implement a network that meets these goals.

INTERACTIVE COMPONENTS

The required components for an on-demand interactive television network are: media server, ATM switch, cable gateway, QAM modulators, and a data channel gateway. These components and their interfaces will be briefly discussed to determine the requirements that each places on the HFC network.

Set-top terminal

The set-top terminal is the consumer interface device. The set-top terminal is designed to receive both analog channels and MPEG-2 digital channels. The set-top terminals are usually designed to receive both analog and digital channels with one 6 MHz tuner.

Since it is necessary to be able to communicate with the set-top terminal while the consumer is watching an analog program, most set-top terminals have an out-of-band data channel. The out-of-band channel is referred to as the Forward Data Channel (FDC).

For on-demand interactive entertainment services, the set-top terminal must have a real-time Reverse Data (RDC) to communicate back to the headend. Both the FDC and the RDC use standard IP protocol for encapsulating messages.

Media Servers

Media servers are large computing platforms that are optimized for delivering MPEG-2 compressed video and audio streams. Proposed servers can deliver from 100 to 250 different 3 megabits per second video and audio streams. OC3 and OC12 interface have been proposed to connect these servers to the ATM switch.

Media servers are designed to be installed in an environmentally conditioned room. They also require much more maintenance than typical cable television equipment. The maintenance required includes: loading and removing assets, replacing disk drives, and cleaning fan filters.

ATM Switch

An ATM switch is required to route the MPEG-2 streams that originate from the media servers. Although the routing of the stream can be done with the media servers, the ATM switch provides for redundancy of media servers and helps tremendously with load balancing and scalability. The input ports on ATM switch are OC3c or OC12c to accommodate the outputs for the media servers. The outputs of the ATM switch are OC3c. The output feeds the interactive cable gateway.

Cable Gateways

The primary purpose of an Interactive or Broadcast cable gateways is to create 'Funny Cable Rates' (FCR). Today there are 2 FCRs, FCR1 that accommodates 64 QAM and FCR2 that accommodates 256 QAM. These rates are needed because they are the rates that can be put into a 6 MHz channel spacing using QAM modulation. FCR1 is approximately 27 megabits per second FCR2 is approximately 36 megabits per second. The input to a cable gateway is a SONET OC3c. The output from the cable gateway is electrical TAXI.

Cable gateways also perform some additional functions that are required including: PID re-mapping, stream encryption, and video and audio re-synchronization.

QAM modulators

Quadrature Amplitude Modulation (QAM) is the preferred modulation method for transportation over the HFC. The QAM channels that are created by the modulators are referred to as Forward Application Transport (FAT) channels. These channels carry MPEG-2 video and audio to the set-top. FAT channels can also be used as high speed download channels to dynamically send new applications to the set-top that the consumer request.

Data Channel Gateway

The Data Channel Gateway (DCG) is used for sending commands and other information to the set-tops terminal. The DCG consists of two primary units, the Forward Data Channel (FDC) modulator and the Reverse Data Channel demodulator and an IP router. Together these two units send and receive all messages for the set-top using standard IP protocol. Additionally, the DCG must provide the timing necessary to synchronize all of the set-tops attached to the coaxial plant serviced by the DCG.

Together these pieces are the primary communication elements that are needed to support an on-demand interactive entertainment system. There are many ways that these elements can be assembled to create an on-demand interactive entertainment system. Next, we will briefly describe Time Warner Cable's HFC network and how we are planning on assembling these components to form a scaleable, cost effective system that can handle high peak loads.

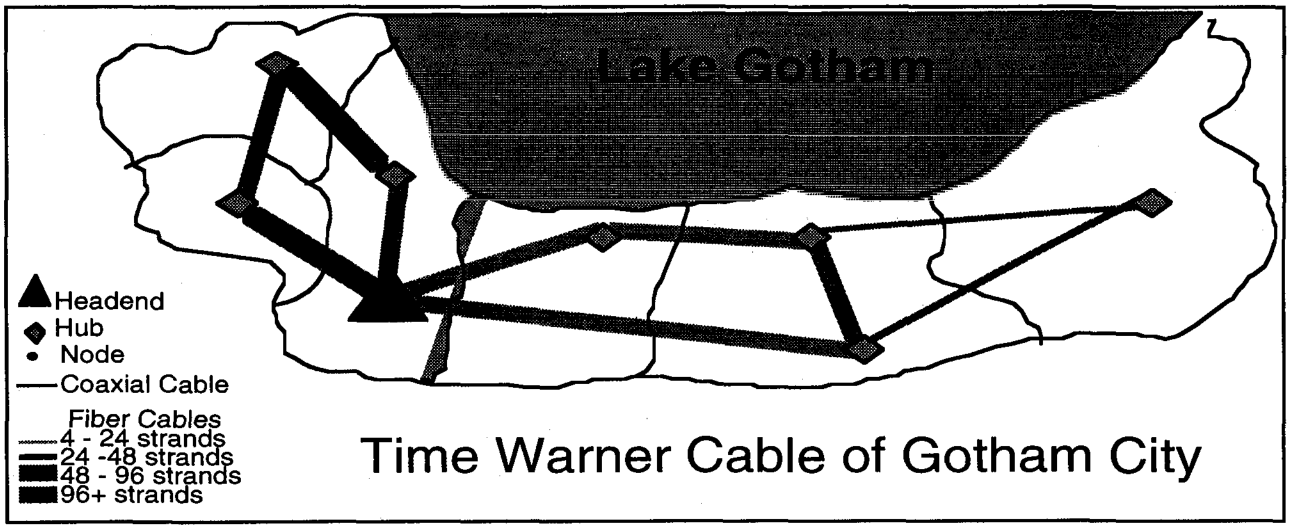

Figure 1 Headend and hub transportation architecture.

TWC'S HFC DESIGN

There are 3 primary parts to the TWC's HFC design, the headend, hubs, and HFC plant. (See Figure 1).

Headend

The headend is the main facility in a cable television system. The headend is the origination point for most of the analog services offered to our customers. This will also be the facility where most digital services will originate, especially early in the deployment stage where penetration of digital set-top terminals is low. This is the facility where the servers, media storage, ATM switches, and QAM modulators are located.

There is fiber optic cable continuity between the headend and all of the hubs in the cable system. Analog and digital channels are transported over these fiber optic cables from the headend facility to the hubs in the network.

The headend is a staffed facility. The headend is an environmentally conditioned location. These are important considerations for equipment like media servers and ATM switches that require frequent maintenance and stable environmental conditions.

Hubs

The Hub in a TWC system is the facility that is used to serve approximately 20,000 home passed. The hubs are connected to the master headend by a ring of fiber optic cables. There are typically 5 hubs on each fiber optic cable ring. Six fiber strands are dedicated to each hub for on-demand interactive entertainment services. There are typically 40 nodes served from a hub. A node typically serves 500 homes passed.

The hubs vary in size from an Optical Transport Node (OTN), which is a large pedestal, to a small building that may be up to 500 square feet. This facility is typically not staffed. There is standby powering at all hubs. All equipment that is located at this facility must be capable of remote monitoring and configuration.

Hybrid Fiber Coaxial Plant

The plant architecture described here is commonly called the Hybrid Fiber Coaxial (HFC) plant. Four parts compose an HFC plant; the transportation fiber optic cables, the distribution fiber optics cables, the node, and the coaxial cables.

The transportation fiber optic cables interconnect the headend to all of the hubs in a logical ring network configuration. The ring provides redundancy to all hubs for analog broadcast signals and the telephony signals. Redundancy may not be provided for on-demand interactive digital services. Typically, five hubs are on each transportation fiber optic cable ring. The distance from the headend to a hub is typically less than 20 miles. If this distance exceeds 20 miles, the signals may be repeated at an intermediate hub, called a transport hub, along the fiber optic cable path.

The Distribution fiber optic cables connect the hub to the nodes in a logical star network configuration. Up to 4 nodes may share one fiber strand in the forward direction. All reverse nodes are served by individual fiber strands. Typically, four fibers are available at each node, but all services are planned to be delivered on one fiber strand. No redundancy is provided at the node. (See Figure 2.)

A node is the optical-to-electrical conversion point. The node converts the forward optical signals into electrical signals for distribution over the coaxial portion of the plant. The node also converts the electrical signals from subscriber set-top terminal equipment in the home into optical signals for delivery back to the headend. The node typically serves 500 homes.

Coaxial cables connect the node to the homes in a logical tree network configuration. Coaxial cables are preferred in this portion of the plant because the electrical signals can be easily repeated with RF amplifiers. Repeating is necessary to overcome the losses of the splitter that are used to feed the homes. Typically, six amplifiers or fewer are in series between the node and a home.

ON-DEMAND TRANSPORT ARCHITECTURE

Figure 3 shows the TWC on-demand transport architecture. The media servers, ATM switches, cable gateways, and QAM modulators are located at the headend. The headend provides an environment that is much more suited for these components in the early phases of deployment. As the demand for service increases, the components at the headend may be replicated to provide for redundancy. A data channel gateway is located at each hub.

Each hub will have six optical fibers dedicated to on-demand services. Four optical fibers are used transport the FAT channel to the hub. Two optical fibers are used to transport signals to the data channel gateway. TWC has chosen to use amplitude modulated fiber-optic links to distribute the MPEG-2 FAT channels to the hubs, but has chosen to use SONET OC3 links to distribute the control signals to the data channel gateway located at the hub. This 'hybrid' transportation approach provides many of the requirements necessary to achieve the goals stated earlier.

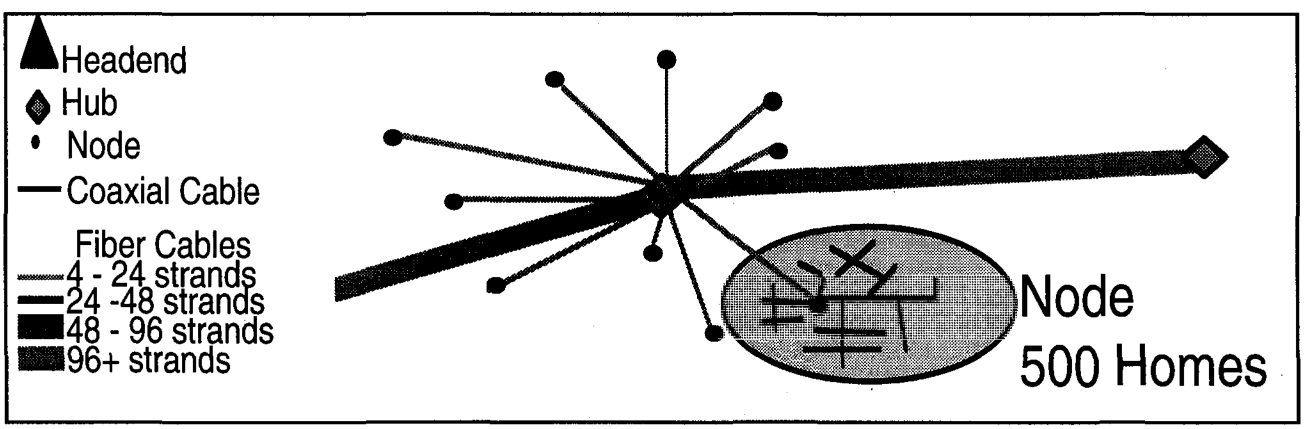

Figure 2 Hybrid fiber coaxial distribution architecture.

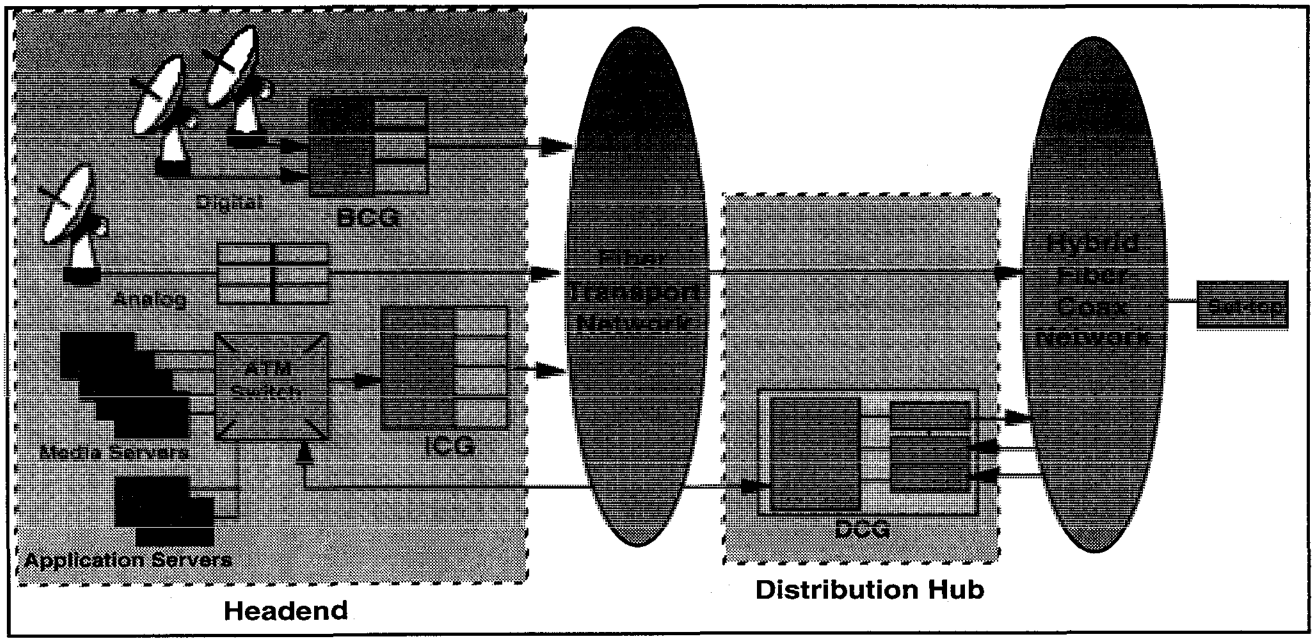

Figure 3 On-demand interactive entertainment architecture.

<u>FAT Channels</u>

When you contrast SONET transport versus amplitude modulated transport on the fiber optic cables, the amplitude modulated fiber optics is the most economical. On a single fiber we are able to transport 621 megabits per second to the hub using frequency division multiplexing. The FAT channels are transported to the hub on the frequencies that they will be carried on over the coaxial cables. At the hub they can be combined passively with the analog channels before distribution to the nodes. If we had chosen SONET OC12, then we would have needed 2 fiber to transport 622 megabits per second of information to the hubs. SONET transport would also have required add drop multiplexers and QAM modulators located at the hubs. Since the hubs are small and unstaffed, this was impractical in many situations.

It is very easy to introduce an on-demand service using amplitude modulated links. You can literally broadcast it to all the hubs, or to some number of hubs. As demand increases, you can segregate the hubs and begin to supply each with dedicated channels. With SONET, you must install the entire infrastructure before you can begin to offer on-demand services. You could start with OC3, but even this is more expensive than starting with amplitude modulated links.

Currently, we are constructing 750 MHz bandwidth plant. This gives us forward channel capacity from 50 to 750 MHz, and reverse channel capacity from 5 to 40 MHz. Current frequency allocation is for analog channels to be in the 50 to 550 MHz range. This gives us capacity for 80 analog channels. The 200 MHz of spectrum from 550 to 750 is reserved for all future services including on-demand interactive entertainment service, PC data services, and telephony services. It is anticipated that 138 MHz of this spectrum will be used for on-demand interactive entertainment services. This provides for 23 FAT channels on the coaxial portion of the plant, or 621 megabits per seconds using 64 QAM modulators. Since there are 4 optical fibers available to a hub, this provides almost 2.5 gigabits per second to a hub that serves 20,000 homes, or enough capacity to simultaneously supply a 3 megabit stream to 4% of the homes.

Data Channel Gateway

Even though we chose to use amplitude modulated links for the FAT channel transportation, we chose SONET for transportation to the data channel gateway.

The Forward Data Channel (FDC) originates at the hub. The Reverse Data Channel (RDC) terminates at the hub. These devices are located at the hubs for the following reasons:

1.Reverse bandwidth can be reused by segmenting the returns from different neighborhoods.

2.Thermal noise power is reduced by segmenting the returns from different neighborhoods.

3.FDC and RDC are typically tied together to synchronize the reverse transmission slot timing for set-tops operating in the neighborhoods.

4.The reverse bandwidth efficiency is increased by minimizing the round trip propagation delay.

The input of the FDC and the output of the RDC at the hub are ethernet. Ethernet is easily remote through SONET. Hubs are typically unstaffed. We need to be able to remotely control and monitor the equipment located at the hubs. Simple Network Management Protocol (SNMP) over ethernet was the most economical choice. Since this is IP-based it can easily be transported over the SONET links also.

There are also some economies when all 3 new businesses are deployed that become available for this relatively low speed data. Once PC data and telephony businesses are deployed, a SONET infrastructure will be installed to the hubs to support them. The bandwidth needed to support the DCG can be piggybacked to these businesses with minimal additional cost. Adding enough SONET equipment to support the FAT channels in a fully deployed entertainment business would still cost more than using separate amplitude modulated fiber-optic links.

SUMMARY

By using a combination of amplitude modulated fiber-optic and SONET links, an on-demand interactive entertainment system can be added to an existing hybrid fiber coaxial network. Amplitude modulated fiber-optic link provides a low cost entry into these new services and can grow as service demands increases. The network infrastructure scales from relatively small peak demands to very high demands, making the modern HFC network very suitable for the evolving future of interactive television.