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## **Telcordia Notes on Cable Networks**

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## **Telcordia Notes on Cable Networks**

Prepared for Telcordia Technologies by: Professional Services

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Technical contact: John Wojewoda

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If further information regarding technical content is required, please contact:

John Wojewoda  
Telcordia Technologies, Inc.  
331 Newman Springs Road, NVC -2Z415  
Red Bank, NJ 07701-5699  
1.732.758.2383  
Email:jwojewod@telcordia.com

For general information about this or any other Telcordia documents, please contact:

Telcordia Technologies Customer Service  
8 Corporate Place, Room 3A-184  
Piscataway, New Jersey 08854-4156  
1.800.521.2673 (USA and Canada)  
1.732.699.5800 (all others)  
1.732.336.2559 (FAX)  
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## Foreword

*Technology* —Webster’s New Collegiate Dictionary defines it as a “technical method of achieving a practical purpose.” A concise, clear definition. But for many, achieving that practical purpose can be more than just a challenge. It can be frustrating, intimidating, time-consuming, and bound to generate the question, “Where Do I Start?”

With the *Telcordia Notes on....* series, Telcordia Technologies has devised a starting point for your search through the rapidly developing world of telecommunications. Written by the authors of the successful *Notes on the Networks* document (SR-2275), this series similarly contains technical material of interest to engineering and planning groups, as well as descriptions of the characteristics and background of these subjects in laymans’ terms. The difference is that *Telcordia Notes on....* zeroes in on *one* technology in each document and breaks it down into manageable terms. From the history, background, and basic elements through a discussion of what the future may bring, our subject matter experts cover the important aspects in as few words as possible.

*Telcordia Notes on....* is a series of Special Reports (SRs) providing the Telcordia proposed view of *general* technical topics. It is *not* a generic requirements document. No part of the text constitutes or suggests a requirement on the part of any entity. Attempts have been made to ensure that information contained herein is recent and reliable. However, due to the constant evolution in technology and its associated documentation, the most current information available regarding topics of interest should be sought. For your convenience, this document contains a Bibliography that lists numerous sources for additional information on the topics presented. This list contains the related generic requirements documents published by Telcordia for the technology discussed in this document. Ordering information for these products is also included.

### About Telcordia Technologies

Telcordia Technologies traces its history back to the divestiture of the Bell System in 1984 when the Bell Operating Companies created a company later called Bellcore that would be a center for technological expertise and innovation. The work that the employees of Telcordia have done since that time has shaped the telecommunications industry, setting a standard for performance and quality unmatched in the industry.

Eighty percent of the United States telecommunications network depends on software invented, developed, implemented, or maintained by us. We hold hundreds of patents, including key patents for broadband data communications technologies such as ADSL, AIN, ATM, ISDN, Frame Relay, SMDS, SONET, DWDM, and video-on-demand.

We currently keep more than 100 million lines of code maintained and running efficiently, through more than 150 operations support systems. Our Capability

Maturity Model Level 5 assessment for software quality leads the industry; our ISO 9001 registration also demonstrates our insistence on quality.

We share our expertise with others, through training and consulting. As the leading consultants to the telecommunications industry, we offer a broad range of expertise, including systems integration, local number portability, unbundling and interconnection, network integrity and reliability, fraud management, and pricing and cost analysis. We are the world's largest provider of telecommunications training services; each year we train more than 30,000 students from 1,300 companies. Companies and individuals come to us because we understand their businesses. We not only know how to build networks, but also how to optimize those networks for the greatest strategic efficiency and accuracy.

And we help our customers transition into the next generation of telecommunications services and equipment. In 1997, Science Applications International Corporation (SAIC), one of the world's largest providers of systems integration and program management, acquired Bellcore and changed our name to Telcordia Technologies. Our new name signals our new status. Our business strategy continues to focus on helping our customers evolve from the current to the next generation of communications technologies. The Telcordia Technologies theme line, Performance from Experience, serves as a reminder of our enormous depth of experience and talent, and our established track record for delivering an exceptional standard of quality.

As Telcordia Technologies, we can provide our traditionally high standard of service and innovation to an even wider range of customers. We help our customers anticipate how their businesses will evolve, and we give them the tools to meet the competitive challenge. In fact, our new name emphasizes the accord we have with our customers and strategic partners. We've demonstrated our ability to achieve accord in complex situations, to keep systems and companies working together efficiently and effectively, and to optimize our customers' networks and their businesses. Look for the Telcordia banner; it's a consistent symbol representing our competitive spirit and teamwork as we move forward toward our goals. We know the path to the future. We've been leading the way there for a long, long time.

For more information about Telcordia Technologies, contact your local account executive or call: **1.800.521.2673** (United States and Canada) or **1.732.699.5800** (in all other countries). On the Web, Telcordia can be reached at <http://www.telcordia.com>.

# 1 Introduction

This Telcordia Special Report (SR) introduces cable network technology, which is a hybrid of fiber access and coaxial access technologies that provide high-capacity network access for residential customers.

The traditional cable network began as a method to deliver broadcast TV signals to areas with poor TV reception. These systems were called Community Antenna Television (CATV). Initially, the cable network was comprised of only coaxial cable from the **headend** (the network backbone) all the way to the subscriber's premises.

Over the years, cable networks have evolved into a hybrid of fiber and coaxial cables known as the **Hybrid Fiber-Coax (HFC)** networks. The HFC network pushes fiber from the headend out to the O/E (Optical/Electrical) node. The O/E node is the point in the network where optical signals are converted to electrical signals, and vice versa. It is the link between the fiber and the coaxial portions of the network. An O/E node can serve anywhere from 500 to 5000 customers. In newer networks, the O/E nodes have been designed and placed in such a way as to be broken down to serve 125 customers if the service demands warrant it.

Cable networks were originally intended to deliver video services to the home. But as bandwidth consumption of Internet services and data applications grew, there became an important need for an infrastructure that could support the delivery of “bandwidth-hungry” applications to the home.

The process of building a new infrastructure to reach residential and business customers that can support the customers' necessary services, Internet speed, security needs, and **Quality of Service (QoS)** became rather expensive.

One of the most practical solutions to this problem involves using the existing infrastructure and improving it. The HFC network is a good example of such an existing network infrastructure, which is employed to support these applications. The original HFC network requires some upgrades to support these Internet and data applications.

## 1.1 Purpose and Scope

This document, which is part of the *Telcordia Notes on ...* series of SRs, provides an overview of cable networks, different architectures, regulations, technical specifications, and the myriad of services that can be supported on the cable network.

Discussions on services and regulation considerations are based on market environments in the United States, unless otherwise stated.

## 1.2 Structure and Use of this Document

The document is organized as follows:

- **Section 2** presents an overview of traditional cable TV networks and the evolution to the modern HFC network.
- **Section 3** looks at the effects the Communications Act of 1934 and the Telecommunications Act of 1996 have had on cable network regulations.
- **Section 4** details the various standards initiatives in the cable industry and discusses the various cable network architectures, including the characteristics and components of these architectures. It also presents the different services offered on today's cable network.

The section also discusses the integration of the cable network with other networking technologies. Finally, the section discusses the different forms of customer premises equipment.

- **Section 5** presents a general overview of the operations and management of the HFC system.

It starts with an in-depth look at the **Telecommunication Management Network (TMN)** and looks at HFC Access Network Management, Data over Cable Management, and Packetized Voice over Cable Management.

- **Section 6** discusses security issues faced by cable network operators and its customers with respect to different service offerings.

The section discusses some of the more typical security threats that the network operators are challenged by and recommendations on measures against them are listed.

- **Section 7** presents evolutionary trends as related to HFC networks. It discusses the near-term and long-term outlooks of the technology.

The section starts with a discussion on technology and market trends followed by a detailed discussion on the road ahead for HFC. It shows that the road ahead for cable operators looks very promising and as these operators look forward to competing head-to-head with telecommunications companies for data and voice customers, network reliability is a main concern.

To stay ahead of the competition, cable operators will need to engineer their network to overcome the challenges they face today.

- **Appendix A** introduces some of the alternative technologies to cable networks for broadband access. These technologies include **Digital Subscriber Line (DSL)**, **Broadband Fixed Wireless Access (BFWA)**, and **Fiber-In-The-Loop (FITL)**.
- **Appendix B** presents a compilation of equipment vendors in the cable industry based on their involvement. Their websites are also included. This list is by no means exhaustive and Telcordia is not recommending any of the products.

- [Appendix C](#) is a detailed Bibliography and References.
- [Appendix D](#) includes complete definitions for numerous HFC terms and acronyms introduced in the document. For your convenience, we have linked the terms in the text to the detailed definitions in [Appendix D](#). A **bold** type (or **color**) is linked to the complete definition.





## 2 Overview of Cable TV Networks

Before the 1990s, the primary purpose of the cable TV system was to deliver a variety of entertainment TV signals to system subscribers. It was *not* intended to be used as a general-purpose communications mechanism.

Cable was built to be a one-way transmission system from a central location known as a **headend** to the subscriber homes, and basically deliver the same signals to all subscribers. These signals were meant to be compatible with the electronics that the subscribers already owned (mainly TV sets).

The TV signals distributed were in accordance with the United States technical standard called NTSC (named after the organization that created it in 1941, the National Television Standards Committee). This black-and-white TV standard was modified in 1953 to provide color information to TV receivers. The standard was modified again to add compatible stereo sound in 1984.

### 2.1 Traditional Cable Networks

Cable began as a method to deliver TV signals to areas with poor TV reception. The earliest systems had receiving antennas located in areas with good reception and coaxial cable distribution of those signals to homes located in areas with poor reception. These systems were called Community Antenna Television (CATV).

The first CATV system was built by Ed Parson of Astoria, Oregon in 1948. It consisted of twin-lead transmission wire strung from housetop to housetop. In 1950, Bob Tarlton built a system in Lansford, Pennsylvania that used coaxial cable on utility poles, made possible through a franchise from the city. The first operators of these systems were retail TV dealers who were trying to promote their products by supplying signals required by their products.

These networks were only required to carry a few TV channels and had bandwidths of only about 250 MHz or enough to transmit the VHF TV band.

Early cable entrepreneurs found cable TV to be very profitable, as TV was sweeping the nation in the 1950s and 1960s. Potential viewers in remote areas were hungry for any TV, and viewers receiving one snowy channel were anxious for a clear picture on three or four channels. The earliest systems did not carry 250 MHz worth of TV signals, but this system capacity allowed the VHF channels to be carried on their own channel assignments, the less to confuse the subscribers.

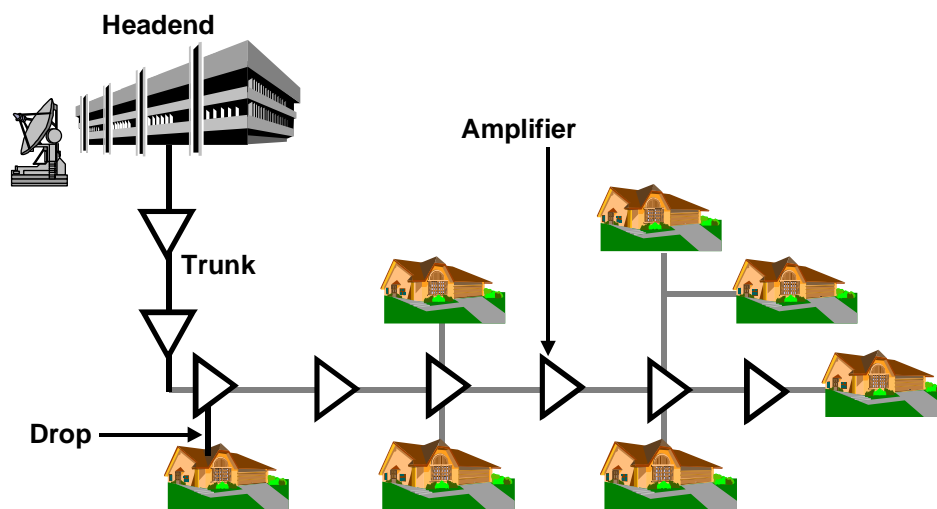
Eventually cable pioneers realized that with the extra capacity on their systems, they could carry distant channels, channels not even within the expectation of the users of a given area. Simultaneously, the idea for cable-only channels was being developed.

Around the same time broadcasters began making their signals available on satellites for cable companies around the country, so were Home Box Office (HBO) and USA Network and other pioneers such as the Entertainment and Sports

Programming Network (ESPN). These satellite services touched off a scramble to provide more bandwidth (to accommodate the new channels). In this fashion the traditional cable network stabilized at around 350 to 550 MHz of bandwidth, although there were always exceptional systems scattered throughout the United States.

The traditional cable TV system is made up of the cable TV headend, trunks, amplifiers, feeders, and subscriber drops.

**Figure 2-1** shows the major components that comprise the architecture of a traditional all-coax cable network. An overview of each of the components follows **Figure 2-1**.



**Figure 2-1** Traditional All-Coax Cable Network

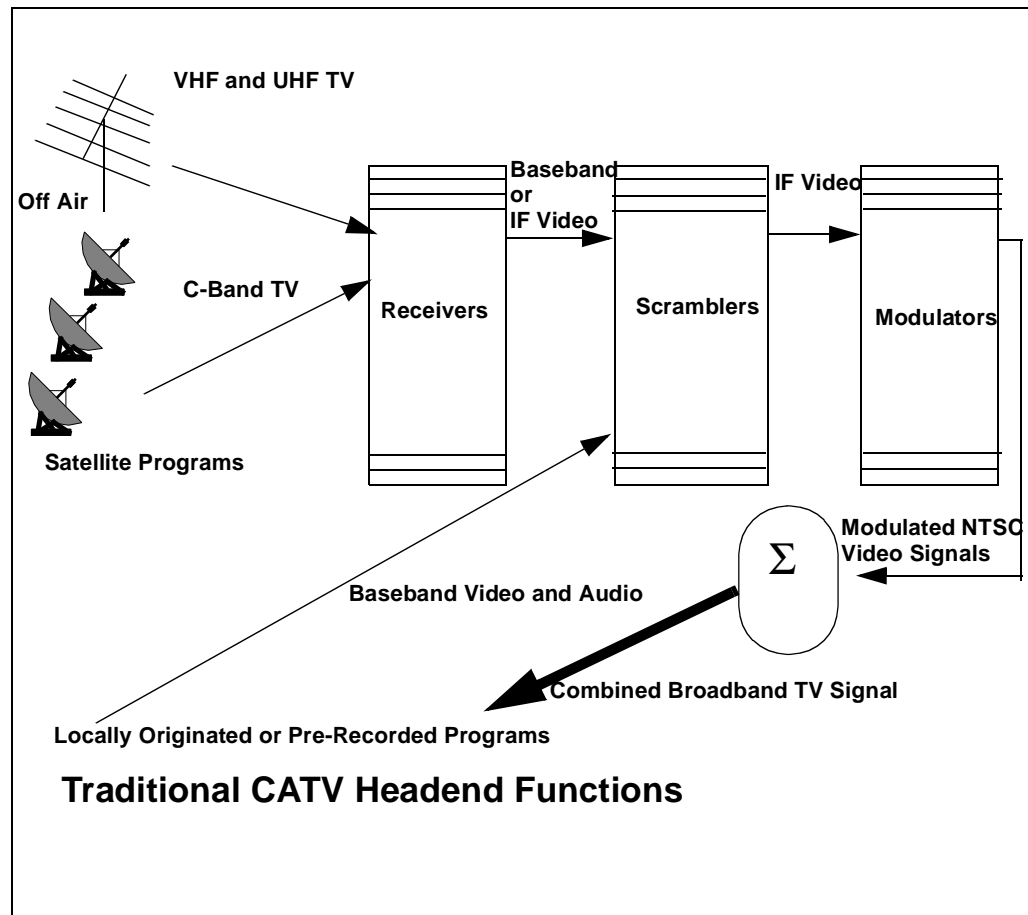
### Central Headend

The headend (top left) is the main TV signal reception, signal origination, and modulation point for the cable TV system. The received 6-MHz TV analog channels are modulated using **Frequency Division Multiplexing (FDM)**. The headend performs the following functions:

- Receives satellite programming
- Receives off-air programming

- Modulates programming onto channel assignments for distribution
- Performs local advertising insertion
- Inserts channels into the trunk system.

**Figure 2-2** shows the traditional CATV headend functions. The headend has the capacity to serve thousands of customers with the use of a simple distribution scheme. The cable originating from the headend is split into multiple cables going to different residential neighborhoods. There is a loss in the signal power as a result of physically splitting (branching) the cable, but the signal content remains the same.



**Figure 2-2** Traditional CATV Headend Functions

### **Trunks**

The trunks are made up of two-conductor coaxial cables. The cables are usually characterized by the diameter of the outer conductor. The bigger the diameter, the lower the attenuation per unit length. So, large diameter coax cables are used as trunks to deliver the signals to the distribution network. Smaller diameter coax cables are used in the distribution and the drop portions of the cable plant.

### **Amplifiers**

The traditional cable systems were designed for large serving areas (e.g., 10,000 homes). In these coaxial networks, the signal is placed on the coax distribution at the headend. To reach all the houses in a particular serving area, the signal must travel many kilometers on the coax. With this distance comes significant attenuation, and to maintain enough power in the signal at the far end, the signal must be continuously amplified. Amplifiers are needed in the cable plant to boost the signal power. It was very common to have as many as 20 or 30 amplifiers in cascade on any given network. The number of amplifiers used is proportional to the number of times the cable is split and the length of the cable. The longer the cable or the more times the signal is split, the more amplifiers needed. Each time the signal is amplified, noise is also added resulting in signal degradation. Thus, the reception is typically better for a house close to the headend than for one many kilometers away. The amplifiers used in the traditional cable network are one-way amplifiers and would need to be changed to two-way amplifiers when upgrading to a two-way cable system.

### **Feeders**

These are sometimes referred to as the distribution network. Feeders are essentially distribution cables, which are smaller in diameter than those of the trunks and are usually short (in a range of 1 to 2 miles).

### **Drops**

The drop cable is the smallest of all the cables in the plant and must be flexible. These could be located on telephone poles or buried in the customer's lawn.

## 2.2 Evolution to Modern Two-Way HFC Networks

Originally, the cable network was one way with no reverse capability. This made sense because cable was originally an alternative delivery medium to broadcasting, and broadcast TV is an inherently one-way activity. Once the multi-channel signal has been assembled at the headend, it is transmitted toward the subscribers.

Large-diameter and relatively low-loss coaxial cables are used in the trunk part of the network. The trunk network is designed to get the signal well out into the service area and is characterized by few taps or divisions of the signals. At designed intervals, the signal is amplified to offset losses that have occurred as a function of transmission distance. Once the signal is out into the service area, smaller diameter cables are used to deliver the signals to individual homes. In this part of the network, more frequent amplification is required because the smaller diameter cables have higher losses and because of the higher frequency of taps.

Why use smaller cables? The network operator is always answering the questions that concern the trade-off of performance and cost. A simple answer is that there is no need to use cables that outperform other aspects of the network. In particular, the effects on picture quality from the sequential modulation and demodulation and multiplexing at the headend, as well as the degradation associated with the set-top box, all have effects that predominate cable quality, but only up to a point.

Two forces helped push the traditional CATV network forward to the modern two-way networks. The first was the need to improve the quality of transmission, i.e., provide a better picture. A crisp, clear, sharp picture is foremost in the desires of cable subscribers. The traditional network would have many repeater amplifiers along the path from headend to subscriber, perhaps as many as a dozen. The resulting degradations from so many amplifiers limited the distance that could be covered from a given headend and thus limited the size of the system geographically to a few score square miles. The emergence of low-loss optical fibers created several exciting opportunities for cable operators, much as they did for other communication network operators.

Among the positive attributes are:

- *Low Transmission Loss.* This is the important attribute. Optical fiber can transmit signals much farther than coax. This allows the network to reach further and with fewer amplifiers. With clever use of optical communications technology, the CATV operator has been able to build metropolitan-area sized networks that share central control and headend functions. Without fiber, operations from a given headend face practical distance limits of a few miles.
- *Electromagnetic Interference Immunity (EMI).* Optical cables do not emit RF energy and are not susceptible to ingress such as radio and TV interference or lighting.
- *Low Maintenance.* Coaxial cables have notorious performance issues with respect to rain and ground water. The attenuation increases rapidly especially for high frequencies when cables are wet. Unlike metallic cables, optical cables

performance does not significantly vary with moisture or temperature. (It is a good idea from a long-term reliability point of view, however, to keep optical cables dry inside and out.)

- *High Capacity.* The bandwidth capacity of a single optical fiber is very high. Fibers not only have large transmission capacities, but many wavelengths of light can be used simultaneously. This gives optical cables a high capacity plus a high upgrade capacity.

However, some complications arise from the introduction of optical fiber. These are:

- *Fiber is better at digital.* Laser-based optical fiber communications can transmit analog signals, but for a variety of reasons, is a natural fit for digital communications. Analog optical systems are a little more expensive to design and build, but they are practical and achievable. The distance an analog link can reach depends on the output power of the laser, fiber, and receiver characteristics, and the characteristics of the analog signal to be transported. For example, a 750-MHz multichannel signal could be carried about 20 km on a typical link without much special effort. The reach could be improved by breaking it into smaller bandwidth pieces. A 250-MHz signal may have a reach of 30% farther or suffer less degradation than the previous example. The digital nature can be exploited in the super trunk applications, where digitized video channels and their associated audio can be transported as needed around the metropolitan area.
- *Increased complexity.* Taken on balance, this is not really true. Certainly field deployment of an O/E node is required to terminate the optical system and feed the coaxial cable signal. The O/E node is a new piece of equipment and a little more complex than a line amplifier. However, in most HFC architectures, a single O/E node (not much bigger than a splice case) replaces all of the amplifiers eliminated by the fiber span, and contains the first amplifier in the direction of the customer.
- *Field power distribution.* Optical cables do not carry electrical power without separate copper pairs for this task. Such pairs are usually not provided as there are no real benefits to having all dielectric cables. Thus power must be provided to this O/E node via a separate power network. In a traditional network the DC power for the amplifiers is sent down the coaxial cable with the signal.

The second force prompting change in the traditional network is the need for two-way communication. The traditional network had the occasional need for information to travel from the subscriber to the headend, but nothing that could not be worked around. Some of these low bandwidth uses included pay-per-view ordering, and online polling. (In the 1970s, there was a system in Columbus Ohio called the QUBE, that allowed live interactive poll response via a handheld unit associated with the set-top box. The user could indicate responses to multiple choice questions. It was popular briefly with polling organizations, talk shows, and politicians!) Despite the fact there was no upstream path, the information could be transported through the telephone network.

If cable networks were ever going to compete for telephony traffic (Internet traffic was not a proven market yet) there was a need to bring traffic upstream as well. It was also noted that interactive Video-On-Demand (VOD) using video servers would require upstream control traffic (such as rewind and pause commands), and online gaming would require much interactive traffic.

The one major block to two-way traffic was the amplifier cascades that keep the video looking good. The amplifiers would have to be replaced with new units that allowed some frequencies to pass upstream. The opportunity to do this coincided with the replacement of most of the cascade with optical fiber.

## 2.3 Evolution of Metropolitan Area Networks

Cable systems have historically been arranged around franchises. Franchise areas have been under the control of the municipal government.

In a relatively simple scenario, a cable operator may have one large franchise such as Washington, DC. In an area laden with independent municipalities such as Northern New Jersey, one or two dozen individual franchises may add up to the DC-sized franchise. Beside the obvious legal and political hassles, there may be inefficiencies at operating over a wide spread area, particularly if the area is not contiguous.

With the advent of high-quality optical fiber transport, the need for a large number of true headends has been reduced, saving equipment and operating costs. Using optical fibers, many signals can be transported around to different “sub” headends, leaving the most expensive headend functions such as satellite and off-air reception, ad-insertion, channel scrambling, and channel modulation to be performed only at the “main” headend. Another advantage is that path redundancy can be included to provide more reliable transport, and some alternate locations for headend functions can ensure a backup in place at all times.

These advantages allow the Metropolitan Area cable network to be operated as a single coordinated business rather than a group of separate cable systems.

## 2.4 Evolution of Gateway-Connected Networks

Once cable networks contemplated Internet services and telephony, there arose a need to provide gateway connections to a backbone network for delivery of services outside the control of the cable company. Not only were traditional networks one-way - from headend to subscriber - there was no traffic for destinations out of the network.

With the advent of telephony and data service came the need to connect to the Internet and to the **Public Switched Telephone Network (PSTN)**. It is now common for the headend to be equipped to groom the upstream traffic and send it to the Internet using a backbone provider. The headend must also route the

downstream traffic to the correct segment of the cable network lest the total amount of traffic overwhelm a given segment. Many systems maintain servers that cache the most frequently requested web-content to speed response time and lower telecommunications costs.

The telephony inter-connectivity can vary in form. Very few cable companies act as local exchanges, rather they connect all of the traffic at a local telephone office of the incumbent carrier.

## 2.5 Why Use HFC?

HFC technology has had a long and sensible evolution as the cable network of choice. Cable networks were initially all coax. Copper networks have their shortcomings, and the emergence of optical fiber cables and related optoelectronics devices in the late 1970s and early 1980s gave cable designers an opportunity to evolve their networks. Copper networks have their strengths as well, with the most important being the ability to be tapped into with low signal loss. There is no analog to the high impedance tap in the optical domain. Any optical tap takes away a noticeable amount of power from the following customers. Thousands of users can share an electrical coax bus connection.

The HFC network then uses fiber where it makes sense - getting from the headend to the neighborhood, and uses coax where it makes sense - in the neighborhood providing a signal to all those homes via taps.

As long as services stay largely asymmetrical, i.e., more downstream than upstream, then the HFC network can be modified to deliver satisfactory services. Telephony, for example, is not asymmetrical but the total bandwidth requirements are small relative to those of entertainment video. Most cable operators will devote the bandwidth below 40 MHz to upstream traffic and use the bandwidth above 54 MHz to perhaps 750 MHz for downstream service, including video, Internet, and telephony.



## 2.6 Cable TV Competitive Environment

For decades cable companies enjoyed franchise-based monopolies, just as monopoly power was exercised by the former Bell System in telecommunications. There was very little competition for cable companies, even from competing technologies such as large satellite dishes until the Communications Act of 1984 and the Communications Act of 1996. Prior to these congressional acts, the cable industry considered its primary competition to be the broadcast industry.

### 2.6.1 Broadcast Competition

With the advent of cable, the consumer could choose between free TV broadcasts and cable, over which the same broadcast signals, and others, were not free. Initially, cable was no immediate threat to broadcasters because of its cost and because it added little extra value. Its subscriber base was largely drawn from areas without acceptable TV reception. At the time, few cable companies had the equipment or wherewithal to include local advertising, an area where cable would provide a direct threat to broadcast revenues.

Broadcasters never saw cable as a way to extend their audience, but rather a way that their audience would become diminished and fragmented, as it has today. This can be seen even in the remote reception example. In an isolated town, the poor to mediocre reception of one or two channels could be improved to good to excellent reception of 3 to 5 channels. The broadcaster has now been brought into competition for viewers and advertisers in these towns.

The broadcast industry is rapidly losing its greatest advantage over the cable industry. Because the broadcast networks attracted the largest mass audience, the broadcasters could afford to out-spend the cable industry on first-run programming. While the broadcast industry still produces a greater volume of first-run programming, it can be observed that pay cable produces equally high quality programming in smaller quantities.

### 2.6.2 Satellite Competition

Satellite reception was originally limited to aficionados and individuals in remote areas. The threat to the industry was so small that none of the transmissions was scrambled. Satellite enthusiasts could watch distant TV stations that were offering their signals to cable systems, view cable services such as ESPN and the Cable News Network (CNN) intended for cable systems, watch Home Box Office (HBO) or a pay-per-view prize fight for free, or even catch the Sunday NFL game of their choice (without commercials!) as the feeds made their way back to New York for network distribution. For a few years the networks considered scrambling the signals, but for many years the cost of scrambling did not equal the value of the lost revenue to the individual entities.

In the early 1980s an early version of direct broadcast satellite using very high powered satellites was attempted and failed [the enthusiasts were using 8- to 20-foot antennas like the cable TVRO equipment, while Direct Broadcast Satellite (DBS) is designed for the consumer to have a 1-foot diameter antenna].

In the 1990s, DBS came back with a new frequency band and a different business model- digital delivery of hundreds of entertainment channels for competitive prices - and is still a strong competitor to cable. The DBS position has only been strengthened by recent court rulings requiring that local broadcast signals be made available to DBS subscribers.

DBS is an inherently one-way system. Most Internet data offerings using DBS have used a telephone modem for upstream communication.

### 2.6.3 LMDS Competition

**Local Multipoint Distribution Service (LMDS)** is a wireless video and data transmission service. Moderately tall towers transmit many video channels and data streams to customers. The customer may have an individual receiving antenna or may be wired to a signal received by a building antenna/tuner on the roof. While LMDS has the advantage of rapid deployment (there are no wires to string to customer homes), it has been most successful in the apartment building community antenna model.

### 2.6.4 Video Rental Competition

One of cables most formidable competitors have been inexpensive video rentals. In areas in which off-the-air reception is accessible, many users will stop at the video rental store for recent first-run movies. This option is very attractive to customers that only want to watch recent film in addition to network and local TV. For such users the superior size of the local store library may be a significant factor.

The promise of watching any video on demand at any time is still in the future.

### 2.6.5 Overbuild Competition

Overbuild competition is the construction and operation of a rival cable network serving the same customer base. Overbuilding is a risky business because it involves direct competition for customers with the likely scenario that neither system will approach a dominant market penetration. There are very few markets in the United States with directly overbuilt competition. In those locations very significant price competition has been observed.

## 3 Cable Network Regulation

Before delving into a more detailed review of the cable network technology in [Section 4](#), this section briefly looks at two important regulatory acts in communications and their effect on the cable network industry: the Communications Act of 1934 ([Section 3.1](#)) and the Telecommunications Act of 1996 ([Section 3.2](#)).

### 3.1 The Communications Act of 1934

Telecommunications network operator's activities are vigorously regulated by a diverse set of governmental bodies. Federal, state, and municipal authorities all play a role in industry regulation. On the Federal level the foundation piece of legislation is the Communications Act of 1934<sup>1</sup> that, while reforming the clutter of pre- and post- world war legislation, provided for the establishment of the **Federal Communications Commission (FCC)**, and set forth policy concerning broadcasting and telecommunications as well as other related fields.

The states had long had public utilities commissions that had the authority to regulate monopoly services such as telephone, in such areas as rates and service levels. Somehow 50 states and the FCC worked well enough together to provide uniform and universal service.

One of the primary regulatory tools is the tariff, which describes in great detail the service to be provided and the price established for such a service. State commissions and the FCC establish the tariff, and it includes information such as the reliability and availability of the class of service, the number and type of wire pairs involved, the method of signaling used, if customer-provided power is required, etc.

The cable industry was initially under the radar screen of regulators, but not for long. Service regulation probably began after the first customer complaints. As cable operators sought to wire local customers, different groups wished to serve the same customers. Still operating under the notion of natural monopoly, municipalities settled the question of which competing groups would get the territory by award of a municipal franchise. Generally speaking, the municipal authority would try to get the best deal for the local town or city, usually awarding the franchise on the basis of perceived ability to provide service and for a price guarantee to customers. It is interesting to note that of the three layers - FCC, state commissioners, and municipal franchise awarders - only the municipal bodies are generally directly elected politicians. (In some states utilities commissioners have been directly elected by voters.)

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1. The full text of the Act can be found at <http://showcase.netins.net/web/akline/1934act.htm>.

### 3.2 The Telecommunications Act of 1996

The Communications Act of 1934 was amended and updated over the years to handle new situations. Even so, it was primarily written in an era dominated by the big broadcast networks and by the Bell System. In 1984, the status quo in United States telecommunications was forever altered with the breakup of the Bell System. The breakup allowed other organizations to compete with the former constituents of the Bell System, and enabled the newly broken parts to contemplate competing in new communications areas such as cable. The FCC began to allow corporations to own increasing numbers of TVs and radio stations. (For many years the FCC allowed a corporation to own only 7 TV stations and 14 radio stations. The concern was to limit the concentration of media power in only a few hands.)

In the era of the status quo, telecommunications was provided by the Bell System and the independent telephone companies, and cable television service was provided by the cable companies. In the 1980s there were hundreds to perhaps a few thousand United States cable companies. The range of size in the cable industry was very wide, from the early Multiple System Operators (MSOs) that owned dozens of large and medium sized cable systems down to the small single franchise “Mom and Pop” cable companies. In a familiar pattern observed in industries as diverse as video rental stores to bookstores to funeral homes, the economies of scale have lead to the shake out of the small scale enterprises in favor of consolidation into large corporations. Today perhaps seven cable companies reach 90% of all United States households.

The Telecommunications Act of 1996<sup>2</sup> is the first major overhaul of telecommunications law in almost 62 years. The goal of this new law is to let anyone enter any communications business - to let any communications business compete in any market against any other - and was a direct response to the desire of newly independent Baby Bells to enter the cable TV market and of the cable companies to enter the telecommunications market. One school of thought has it that the consolidation in the cable industry is needed to compete on an equal basis with the highly capitalized telecommunications companies.

Despite the big changes in the 1996 Act, Congress intended it to modify and supplement the 1934 Act. Of particular interest to cable TV networks providing video and telecommunications services are the following sections of the two acts.

#### **The Communications Act of 1934**

- Title II concerns Common Carriers such as telecommunications providers.
- Title VI of the act was amended to cover cable communications, including definitions of cable services and technical requirements of such systems.

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2. The full text of the Act can be found at <http://www.fcc.gov/telecom.html#text>.

### **Telecommunications Act of 1996**

- Title 1 defines telecom services and makes distinctions between “Bell Companies” and others. It also sets guidelines for determining whether or not markets are competitive, crucial to allowing Bell Company entry into these markets.
- Title III concerns cable TV activity, specifically describing cable activity by telecommunications companies and the circumstances under which FCC exercises pre-emption of municipal franchising authority.

### **3.3 Regulatory Summary**

In today’s environment, municipal governments award cable TV franchises to settle who will get the territorial rights. Usually a city council or other legislative body decides on the basis of service and rate promises. It is interesting to note that such bodies have tried to regulate other services such as Internet access speeds with little success. States have the authority to control or deregulate rates on telecommunications services. Generally the state utility commissions are not as involved with cable type services as they are with telecommunications services. The state commissions set service levels through tariffs.

The FCC regulates cable and telecommunications services and networks. The FCC also uses tariffs to set certain service levels, and sets technical standards for a variety of services. Depending on the political climate, the FCC has been involved with the regulations of cable rates, and at other times taken a hands off policy. The FCC has also tried to enable competition in the cable, telecommunications, and Internet access areas.



## 4 Cable Networks

### 4.1 Technology Overview

Cable networks have evolved from their all-copper, all-coaxial past. To enjoy the benefits of lower operating costs and increase the service bandwidth to the customer, cable providers have migrated to the **Hybrid Fiber-Coax (HFC)** network. As **Section 2** states, the HFC network pushes fiber from the **headend** out to the Optical/Electrical (O/E) node. The O/E node is the point in the network where optical signals are converted to electrical signals and vice versa. It is the link between the fiber and the coaxial portions of the network. An O/E node can serve anywhere from 500 to 5000 customers. In newer networks, the O/E nodes have been designed and placed in such a way as to be broken down to serve 125 customers if the service demands warrant it.

This section expands on the material introduced in **Section 2**.

- **Section 4.2** discusses the standards initiatives undertaken in the cable industry. It starts with important pre-cable standards and then discusses current cable standards with respect to voice, video, and data.
- **Section 4.3** discusses the HFC system architectures and components.
- **Section 4.4** discusses the service capabilities of HFC networks.
- **Section 4.5** reviews how HFC networks can be integrated with other data networks such as the **Internet Protocol (IP)** and **Asynchronous Transfer Mode (ATM)**.
- **Section 4.6** describes different **Customer Premises Equipment (CPE)** applicable in HFC networks.
- **Section 4.7** discusses the limitations and issues facing HFC networks.

## 4.2 Standards Initiatives

Historically, the cable industry has not sought nor initiated standards activities; however, there were already component standards for most of the hardware a cable network would use. These standards were developed for other industries or by cable suppliers that had other electronics markets. Regarding system standards, the industry used the defacto standards of the few dominant suppliers in the industry. Those defacto standards covered items such as the interaction of the **set-top converter box** and the **Synchronous Optical Network (SONET)**. NTSC and the FCC took care of most video standards.

In the last decade the cable industry has ventured into new territory. The old services were decidedly broadcast in nature. The new services are two-way and interactive. This has pushed the cable industry into not only embracing existing system standards, but even in principle the participation and formation of cable-oriented standards bodies.

The FCC has made one strong push in the direction of standards. It has tried to get the cable industry to make set-top boxes and other home terminals available for sale to consumers as an alternative to the then hidden rental fees for the same.

Because customers who purchase a set-top box and a **Cable Modem (CM)** would like some assurance that their equipment will work when they move across town or across the country, and because cable operators and related equipment manufacturers have a vested interest in ensuring that set-top boxes and CMs purchased in retail stores will work, vigorous and certifiable standards are needed.

### 4.2.1 Important Pre-Cable Standards

#### 4.2.1.1 National Television Standards Committee (NTSC)

The National Television Standards Committee (NTSC) was responsible for creating the United States technical standard called NTSC. The black-and-white TV standard was created in 1941 and was modified in 1953 to provide color information to TV receivers. The standard was modified again in 1984, to add compatible stereo sound.

The NTSC has a vertical resolution of 525 horizontal lines per frame (complete screen image). The lines are scanned from left to right and from top to bottom. It takes two screen scans to complete a frame because every other line is skipped. One of the scans is for odd-numbered horizontal lines and the other is for even-numbered lines. The odd and even fields are interlaced to form the full frame.



#### 4.2.1.2 Society of Cable Telecommunications Engineers (SCTE) Digital Video Subcommittee (DVS)

The Society of Cable Telecommunications Engineers (SCTE) was created in 1969 to promote the sharing of operational and technical knowledge in the cable TV and broadband industry. In 1995, the American National Standards Institute (ANSI) accredited SCTE as the standards development organization for the broadband industry. The SCTE established the Digital Video Subcommittee (DVS) in 1996 with the goal of exploring “the need for SCTE involvement in the development of standards for video signal delivery...”

#### 4.2.1.3 Joint Engineering Committee

The Joint Engineering Committee was formed in 1980 by the National Cable Television Association (NCTA) and the Consumer Manufacturers Association (CEMA). The function of the committee was to provide a forum where technical representatives from the cable and consumer electronics industries could find ways to make cable service and consumer-electronics products more compatible. It developed the EIA-542 Cable TV Identification Plan (frequency plan) and the ANSI/EIA 563 Decoder Interface Standard.

#### 4.2.1.4 Digital Audio Video Council (DAVIC)

The Digital Audio Video Council (DAVIC) is an international organization with the goal of establishing “internationally agreed specifications of open interfaces and protocols” that will permit “interoperability across countries and applications/services” for the delivery of services “with prevalent digital audio video component.”

DAVIC is a non-profit association based in Switzerland, with a membership of over 157 companies from more than 25 countries. The first version of their specification, DAVIC 1.0, was released in June 1995 and the most recent version, DAVIC 1.4 was released in September 1998. All the versions of DAVIC specifications, 1.0-1.4, are backwards compatible. The DAVIC specification has been accepted by ISO/IEC JTC 1 as an International Standard ISO/IEC 16500.

#### 4.2.1.5 IEEE 802.14 Cable Modem Working Group

The IEEE 802.14 Cable Modem Working Group was formed with the goal of producing standards suitable for two-way transmission of multiple services over cable TV systems. Its job was to define a **Media Access Control (MAC)** standard and physical layer standard(s) to support multimedia services over HFC. The services include high-speed data communication to computers in homes and businesses, compressed video for conferencing and video phone calls. In addition, the working group sought to provide support for applications like interactive games

and video shopping. The working group missed the target delivery date which caused the cable operators to start a new standards process.

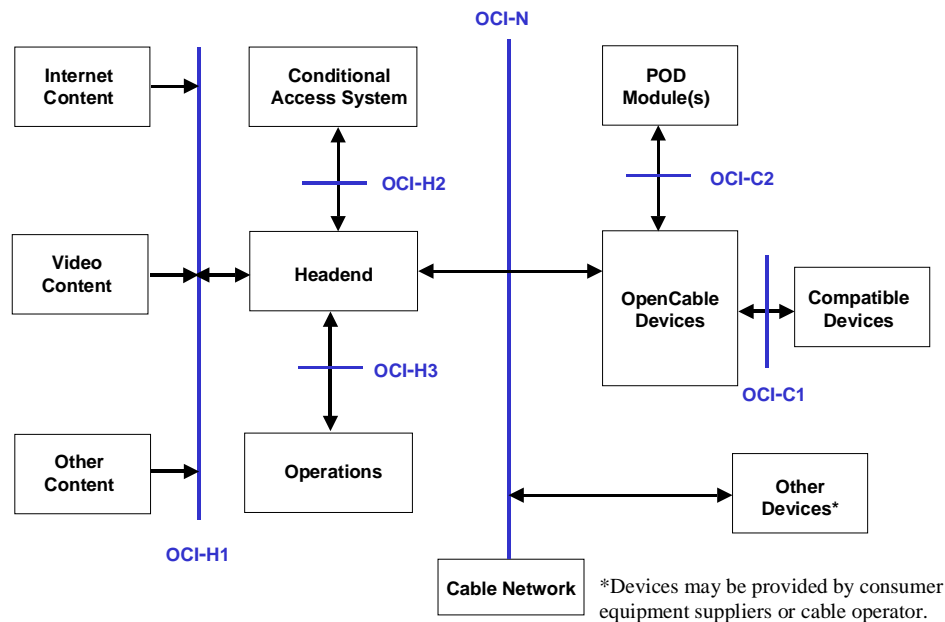
#### 4.2.2 Video (OpenCable™)

OpenCable™ is an initiative of the United States cable TV industry and is being managed by CableLabs®. OpenCable was initiated in the spring of 1997 with the goal of creating a new generation of terminal devices that are interoperable across cable systems in North America, and can be manufactured by multiple vendors. Working groups were established to facilitate a set of specifications that define key interfaces and core functional requirements for OpenCable devices.

The OpenCable initiative has a number of components. First, it is the process by which advanced terminal devices, including set-tops, will be defined; second, it is a blueprint for a way of delivering a series of advanced services to consumers; third, it is a family of cable digital devices; and fourth, it is a consumer brand.

This open standard is intended to promote competition among the suppliers of the key elements of digital cable networks and also to ensure interoperability among the devices connected to the cable networks. Proprietary solutions are discouraged thereby leading to competitive pricing for set-top boxes and introduction of cable-ready TV sets and set-tops into retail distribution.

The reference model and architecture for OpenCable is shown in [Figure 4-1](#).



**Figure 4-1** OpenCable Reference Model and Architecture

The OpenCable process generated the specifications for the six interfaces defined in the **Figure 4-1** reference model. There are three headend interfaces (OCI-H1, OCI-H2, and OCI-H3), a network interface (OCI-N), and two consumer interfaces (OCI-C1 and OCI-C2). These specifications are created to spell out for manufacturers and others how to build products compatible with the OpenCable architecture and ensure interoperability among these devices.

The following is a brief description of the interfaces mentioned above:

- *OCI-H1 interface:* The information flowing through the OCI-H1 interface is made up of programming content from three main sources. These sources are Internet, video, and any other kind of information that arrives at the headend. The goal of the OCI-H1 interface is to define a standard content format for all digital services.
- *OCI-H2 interface:* The OCI-H2 interface defines the standard that supports the separation of conditional access functions from service delivery functions. A conditional access system provides the way by which the user is granted access to specific pre-paid services.
- *OCI-H3 interface:* This interface provides operational and control flows between the headend components and the other systems that are required to

operate the cable system, including billing systems, subscriber management, operational support systems, network management systems, etc.

- **OCI-N interface:** This is the network interface and it is the most important of all the OpenCable interfaces because it supports the plug and play of set-tops, cable-ready TVs, or other devices to the OpenCable networks. It defines all the digital channels (in-band and out-of-band) and in-the-clear analog NTSC channels.
- **OCI-C1 interface:** The OCI-C1 interface connects the OpenCable device to any consumer electronics in the house, including TV, VCR, and any external audio systems. The OCI-C1 provides support for a digital interface from a digital set-top to the TV receiver, high definition services (e.g., HDTV), the cable user interface with a single remote control. It also provides content copy protection. More information on content protection is available in [Section 6](#) of this document.
- **OCI-C2 Interface:** This is the interface to a Point of Deployment (POD) module for digital signals provided over the cable system. The POD module is a PCMCIA-format device supplied by the cable operator for security and signaling support.

#### 4.2.3 Voice and Data (DOCSIS)

The [Data Over Cable Service Interface Specification \(DOCSIS\)<sup>TM</sup>](#) was developed by CableLabs and approved by the [International Telecommunication Union \(ITU\)](#).

DOCSIS defines the interface standards for cable modems and supporting equipment. DOCSIS also provides for interoperability among different vendor equipment, so consumers no longer have to depend on leased cable modems from their cable providers. Other devices that recognize and support the DOCSIS standard include HDTVs and Web enabled set-top boxes for regular TVs.

[Section 4.4.2](#) provides more information on the DOCSIS protocol.

#### 4.2.4 Real-time/Multimedia Services (PacketCable)

PacketCable is a CableLabs-led initiative aimed at developing interoperable interface specifications for delivering advanced, real-time multimedia services over two-way cable plants. Such applications include IP telephony, multimedia conferencing, interactive gaming, and general multimedia applications.

Built on top of the DOCSIS 1.1 cable modem infrastructure, PacketCable networks use IP technology as the basis for a very capable multimedia architecture. A DOCSIS 1.1 network with PacketCable extensions enables cable operators to deliver data and voice traffic efficiently and economically using a single high-speed, [Quality of Service \(QoS\)](#)-enabled broadband architecture. Working with CableLabs member companies and technology suppliers, the PacketCable project

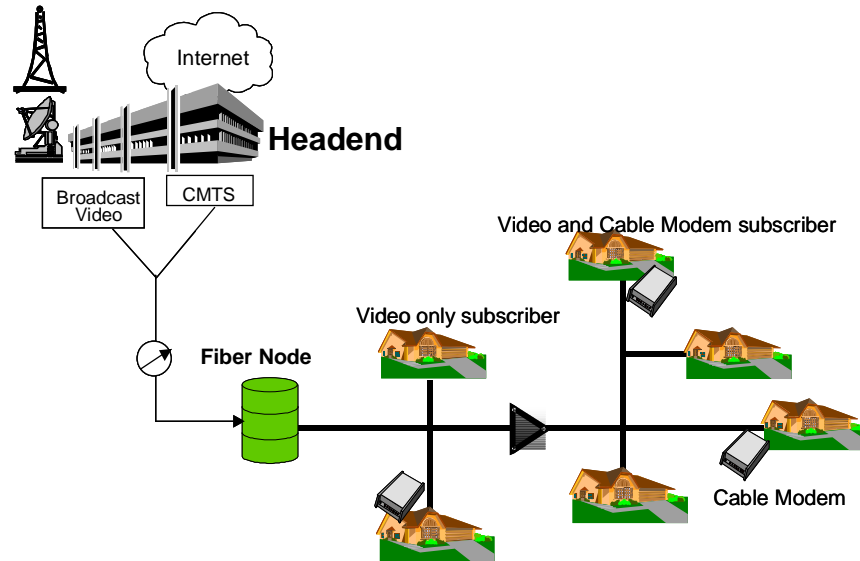
will address issues such as device interoperability and product compliance with the PacketCable specifications.

Together, PacketCable and DOCSIS 1.1 provide an integrated solution that enables high-quality voice and data services to be delivered over the same two-way HFC cable plant. [Section 4.4.4](#) provides more information on PacketCable.

### 4.3 Basic HFC System Architecture

A high-level view of an HFC system is shown in [Figure 4-2](#). The HFC system is made up of the headend/distribution hub, access network, and the subscriber network. The HFC access network consists of a hybrid of fiber and coaxial cable. The fiber extends from the headend to the fiber (O/E) nodes in the residential neighborhood and connects to an amplified tree-and-branch coaxial feeder cable. The fiber node can serve 500 to 2000 subscribers via coaxial cable [drops](#). The fiber node typically has a couple of coax legs extending from it in different directions and generally has no more than four amplifiers in cascade.

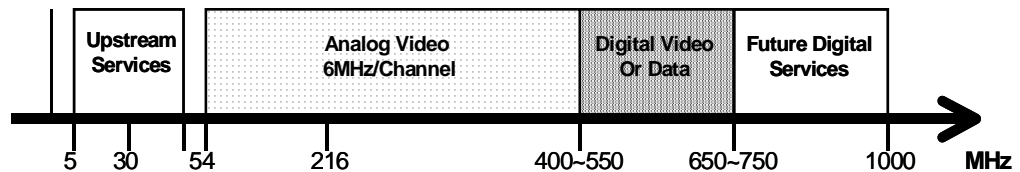
Unlike traditional cable networks, HFC significantly reduces the number of amplifiers between the headend and the customer location. This improves the signal quality and reliability as amplifier failure is the leading source of service outage in cable TV networks. The modern HFC system can deliver a combination of analog video, digital video, telephony, data, and any other narrowband or broadband service. The signal from the headend destined for the subscriber is modulated and sent to a laser transmitter for transmission over the fiber cable to the fiber node. At the fiber node, the optical signal is translated into electrical signals before being placed on the distribution coax.



**Figure 4-2** High-Level Architecture of an HFC Network

In the current HFC or coax network, analog video signals are collected from satellite dishes and off-air antennas at a headend. Each video signal occupies 6 MHz of spectrum. The video signals are frequency shifted or **modulated** onto an assigned channel and combined into one signal ranging in frequency from 54 MHz to typically 750 MHz. This signal is then sent to a laser transmitter, which sends the signal over analog fiber to one or more fiber nodes. For upstream communications [for data, Impulse Pay Per View (IPPV), etc.] the frequencies from 5 MHz to 42 MHz are used.

**Figure 4-3** depicts the frequency allocation for cable network services.

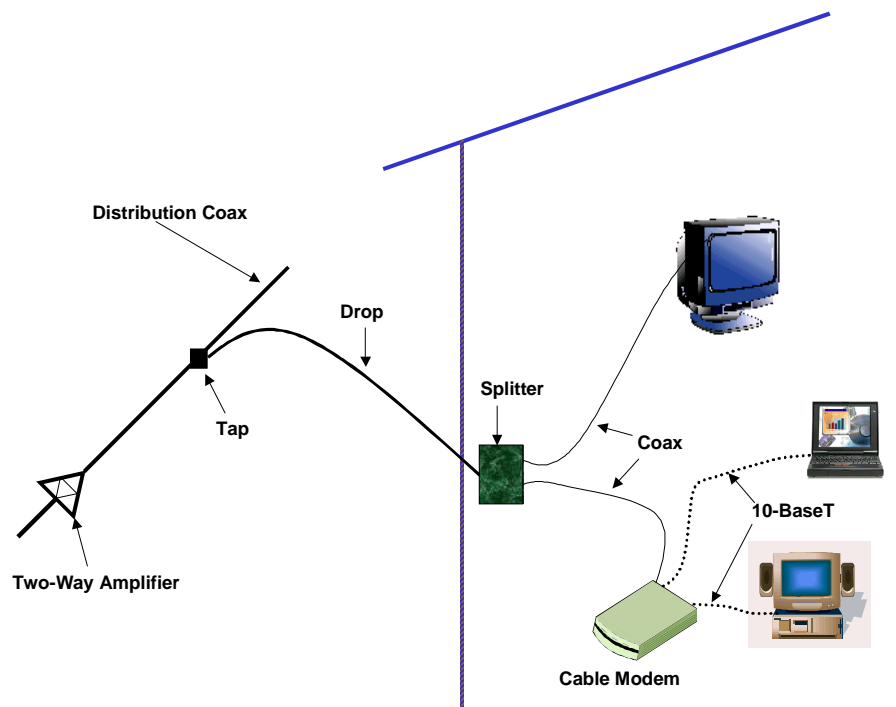


**Figure 4-3** Frequency Spectrum Allocation for Cable Network Services

An important characteristic of the modern HFC network is in its ability to allow two-way communications (i.e., allow transmissions in both directions). Transmissions from the headend to the subscriber are referred to as downstream while transmissions from the subscriber to the headend are referred to as upstream. The traditional cable TV network is only used to send analog TV programs to subscribers and there is no upstream transmission because the amplifiers used provide only one-way capability. But to support communications on the cable networks, the amplifiers must be bi-directional. Also, the optical node requires a laser transmitter in addition to the receiver. Similarly, the headend requires a receiver in addition to the transmitter.

Cable modems utilize an HFC network to deliver high-speed data to the home. This is done by placing a **Cable Modem Termination System (CMTS)** in the headend (see **Figure 4-2**) and a cable modem at the subscriber's premises. The CMTS is an important addition to the cable TV network, because it supports the integration of downstream and upstream communications over the cable network. The CMTS and cable modem pair allow broadband data services to be offered over the cable plant. One CMTS can support many cable modem subscribers. The CMTS modulates the downstream data into a 6-MHz channel. This data channel is then combined with other video channels and broadcast over the fiber and coax on the downstream. On the upstream, the CMTS receives the data and demodulates it, and sends it to the backbone transport for delivery to its final destination.

**Figure 4-4** shows the configuration of the cable customer's network supporting data services on a two-way cable network.



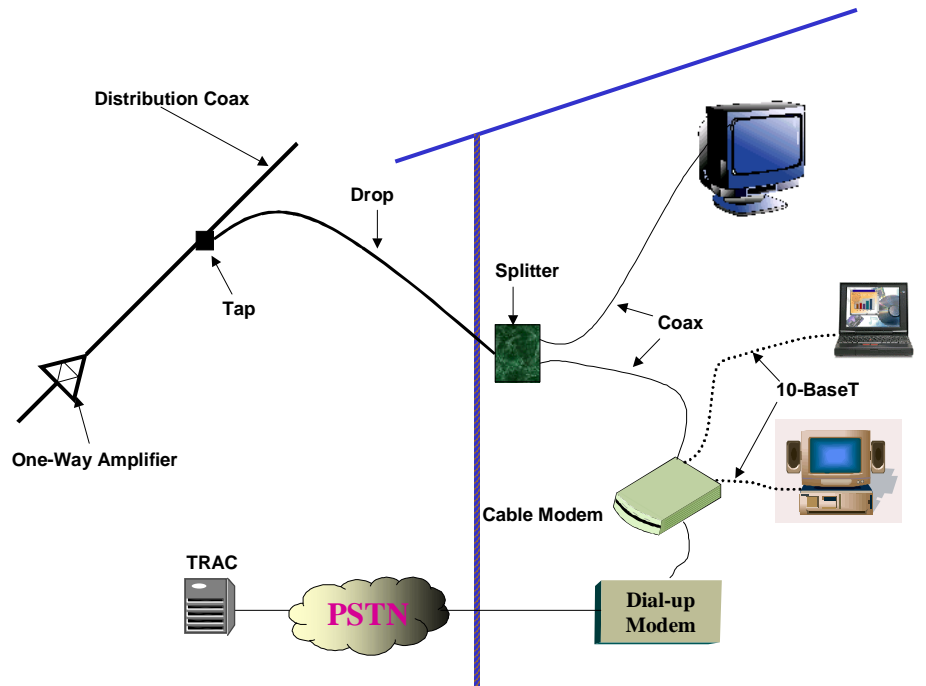
**Figure 4-4** Customer Premises Network Supporting Two-Way Data Services

The data is delivered to the subscriber's premises on the same coaxial drop as the cable TV service. The signal is split with a two-way splitter, with one going to the customer premises network for video distribution and the other going to a cable modem. The modulated data signals are terminated and demodulated at the cable modem. The cable modem is connected to the PC or laptop via an **Ethernet** or USB connection. Most cable modem services are asymmetrical, and deliver data rates ranging from 27 Mbps to 38 Mbps to the customer, but support between 320 kbps to 10 Mbps returning from the customer.

### 4.3.1 One-Way Cable Networks with a Telephony Return

A cable system with a telephony return utilizes the HFC network for downstream transmissions only. The upstream signal relies on the existing telephony network for transmission. This enables companies to enter the market quickly without having to make time-consuming and costly upgrades to their cable plant. Also, cable systems with telephony returns enables data service to be offered when such upgrades are not economically justifiable.

**Figure 4-5** shows an architectural overview of a one-way cable network with a telephony return path. With an analog modem, the cable modem sends IP datagrams upstream via the **Public Switched Telephone Network (PSTN)** using the **Point-to-Point Protocol (PPP)**, as specified in RFC 1661.



**Figure 4-5** One-Way Cable Plant with a Telephony Return Path

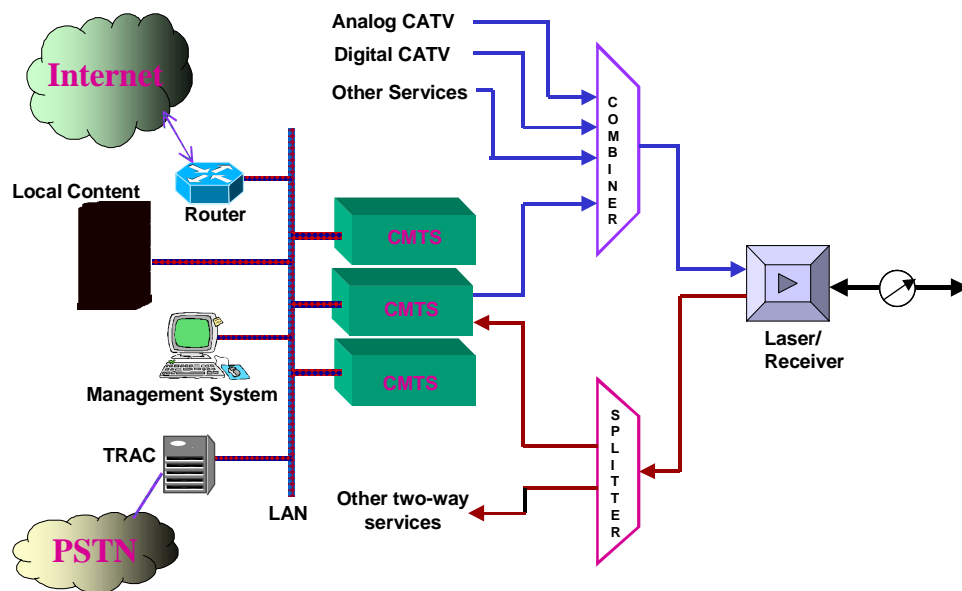


To offer services using a one-way cable system with a telephony return, a **Telephony Remote Access Concentrator (TRAC)** needs to be added to the cable network. The TRAC is the device that terminates and decodes the dial-up **Point-to-Point Protocol (PPP)** sessions from the cable modems before sending them to the final destinations. The TRAC may be situated in a location other than the CMTS, but it should have routing associations with the CMTS.

### 4.3.2 Headend Equipment

In the traditional cable TV networks, the primary function of the headend is the reception of TV channels collected from various sources such as broadcast TV, satellite, local community programming, and local content insertion. With the emergence of other services such as high-speed data and **Voice over Internet Protocol (VoIP)**, the headend equipment plays an important role in intercepting and routing the traffic generated by these new services to the appropriate part of the network.

**Figure 4-6** depicts a functional diagram of a headend supporting multimedia services.



**Figure 4-6** Functional Diagram of a Headend

The data coming from the individual subscriber's cable modem is filtered by upstream demodulators or TRAC and is then further processed by the CMTS, which routes data from many cable modems over a multiplexed network interface.

The information coming from the Internet passes through the router to the headend **Local Area Network (LAN)** and then is routed to the appropriate CMTS. The downstream data is sent to a 64/256-**Quadrature Amplitude Modulation (QAM)** modulator, where it is digitally modulated into one of the 6-MHz channels. The cable headend then combines the downstream data channels with video, pay-per-view, audio, and other services before transmitting through the cable distribution network to the subscribers.

The HFC network is a shared media and the subscriber modems have to contend to gain access to the upstream. Therefore, there is a need for some form of access control within the CMTS.

**Media Access Control (MAC)** layer protocols control how the upstream bandwidth is shared among multiple simultaneous users on the same channel. For the MAC protocol to function properly, the cable modem must know when the upstream channel is being used by some other modem. However, because of the nature of the HFC distribution plant, the cable modem cannot "listen" to the upstream transmission frequency. The MAC layer protocol allows the CMTS to indicate which modem has the right to transmit and the duration of the transmission. The DOCSIS MAC protocol uses a request/grant mechanism, where a modem requests an opportunity to transmit a specific amount of data.

The upstream link is divided into mini-slots. The CMTS receives the requests from all cable modems and grants mini-slots on the upstream path. The CMTS periodically broadcasts a message to the modems over the downstream link specifying the mini-slots granted to each modem. This kind of reservation ensures a collision-free transmission by the modems. Bandwidth is allocated to modems based on the kind of service subscription. The modem has to contend to transmit a request for a mini-slot if it has never been allocated one. The CMTS allocates slots for such requests periodically. If there is a collision with a request from another modem, the modems involved will back off randomly before attempting to retransmit the requests.

One issue of concern is the distances that the cable system must cover. A single node serving 500 homes may have a subscriber that is 50 or 100 km from the headend. If one channel serves multiple nodes, the longest distance between any two subscribers may be even further. The communication between the CMTS and the cable modems is delayed due to latency, propagation delay, and processing overhead. The combination of these delays causes the cable modem to transmit either earlier or later than the assigned mini-slot, which could result in collisions.

Ranging is used to hide all these delays and present the cable modems as equidistant from CMTS. The ranging process is first performed during an initial maintenance transmit opportunity when the modem first connects to the network and is repeated at regular intervals. The modem transmits a ranging request message in one of the

contention mini-slots to the CMTS. If no response is received within a time-out period, the modem assumes that either there was a collision with a ranging request message from another modem or its transmit power is too low for the CMTS to detect. The modem increases its transmit power and backs off randomly before attempting to retransmit the ranging request message. Upon receiving a ranging request message, the CMTS notes the time offset from when it received the ranging request to the beginning of the initial maintenance transmit opportunity, the exact frequency of the transmission, and the incoming power level. The CMTS uses this information to determine corrections and sends these adjustments back to the modem in a ranging response message. This ensures that each modem transmits in its own mini-slots without the risk of a collision. After receiving a ranging response, the modem adjusts its parameters based on the corrections and transmits a second ranging request to the CMTS. The CMTS in turn transmits a ranging response with time, frequency, and power corrections. This process continues until the accurate timing, frequency, and power settings being used by that modem has been determined.

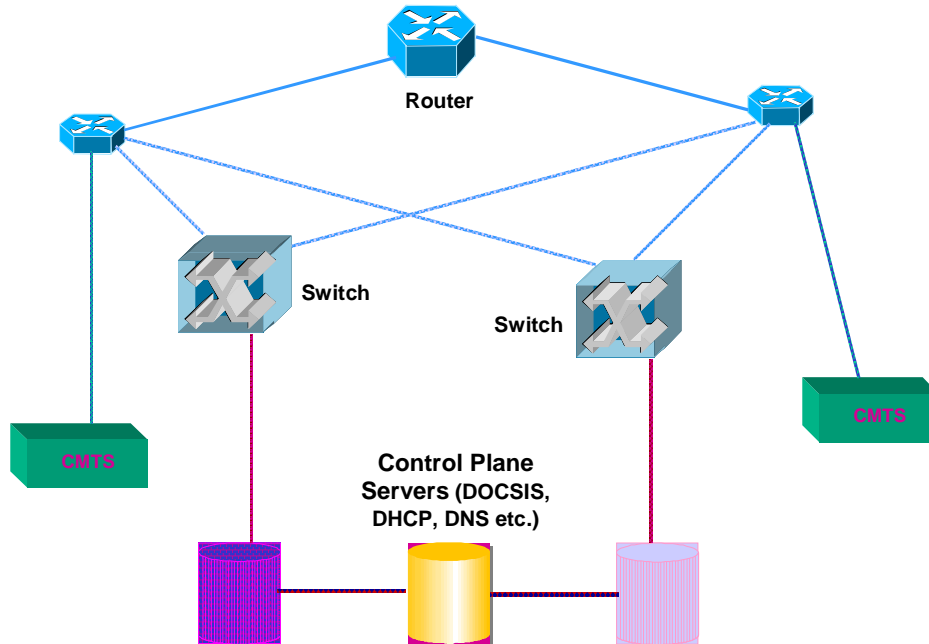
### 4.3.3 Cable Data Network Architecture

The cable data network architecture is similar to that of an office **Local Area Network (LAN)**. The CMTS is the device that provides an extended **Ethernet** network over the **Wide Area Network (WAN)**, which could extend for up to 100 miles. The cable data network could be under the control of the local cable operations unit or could be managed by a regional data center, where all the operations of several cable headends are aggregated. The daily operations and management of the cable data network could be combined at a single location, e.g., at a super hub, or the headend could be locally managed as basic hubs (see **Figure 4-6**).

The super hub (headend) is a cable headend site with additional temperature-controlled facilities, which house servers necessary to run the cable data network. These servers include, among others:

- Authorization, Authentication, and Accounting (AAA) servers
- DOCSIS control servers
- **Domain Naming System (DNS)** servers
- **Dynamic Host Configuration Protocol (DHCP)** servers.

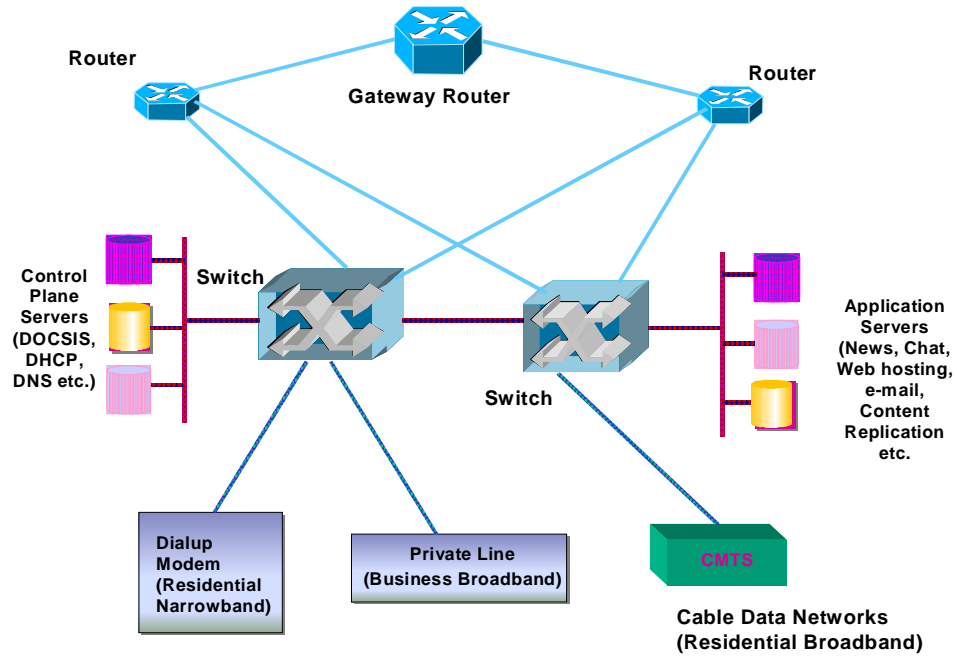
The super hub provides connectivity among the production network, network management/surveillance equipment, backbone network, and external networks. **Figure 4-7** shows a high-level view of a super headend.



**Figure 4-7** High-Level View of a Super Headend

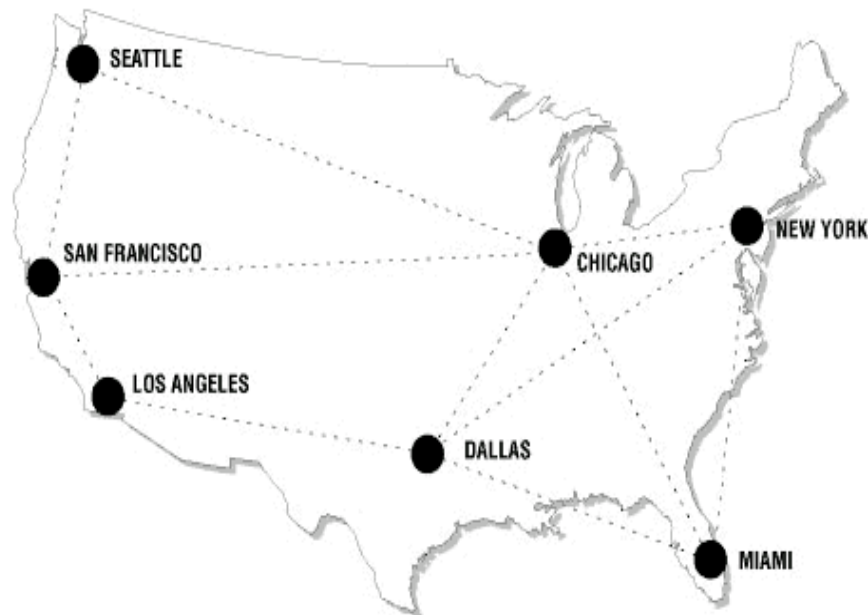
The data from the basic and super headend locations is sent to a regional data center, where it is aggregated before distribution throughout the network. The regional data center provides connectivity to the Internet and the World Wide Web; it contains the servers necessary to support Internet services such as electronic mail, web hosting, news, chat, etc.

**Figure 4-8** shows a high-level view of a regional data center.



**Figure 4-8** High-Level View of a Regional Data Center

Finally, the regional data center is connected to other regional centers by a national network, as **Figure 4-9** shows.



**Figure 4-9** The National Cable Data Network

#### 4.3.4 Fiber Transmission

In cable networks, optical fibers are used in the access portion to feed the O/E nodes. Fiber is also used to “super trunk” digital and analog signals from one location to another in metropolitan area cable networks. Finally, optical fiber is used in the backbone networks that bring traffic in and out of metropolitan areas.

#### 4.3.5 Coaxial Transmission

Coaxial cable is the historic transmission medium of the cable network. The coaxial cable attenuates the signal traveling through it. To cover a large serving area, there is a need for periodic insertion of amplifiers to maintain enough signal power at the far end. The type and size of the coaxial cable determines the amount of loss the signal experiences. Also, whenever the cable is split or tapped to serve customers, the signal is degraded. Each amplifier is intended to compensate for all transmission losses experienced in that section of the plant.

## 4.4 Service Capabilities of Cable Networks

While cable networks have been deployed primarily to carry video, a cable network should support multimedia services and deliver these services relatively close to (or even into) the customer premise.

This section discusses seven service types:

- Broadcast Video - analog and digital ([Section 4.4.1](#))
- Data over Cable ([Section 4.4.2](#))
- Analog Voice over Cable ([Section 4.4.3](#))
- Digital Voice over Cable ([Section 4.4.4](#))
- Interactive Services ([Section 4.4.5](#))
- On-Demand Services ([Section 4.4.6](#))
- Electronic Program Guide ([Section 4.4.7](#)).

### 4.4.1 Broadcast Video

Broadcast video is transmitted in a cable network in such a way that the signal reaches all subscribers all of the time. This does not mean that all cable subscribers subscribe to every broadcast video service. Rather it means that broadcast signals reach virtually all points of the network at the same time. The broadcast signals may be denied to non-subscribers by use of scrambling, encryption, or interdiction schemes. The vast majority of the bandwidth in modern cable networks is broadcast.

The true alternative to broadcast video would be switched video. A service provider would make a program available to a single or small group of subscribers. Only the subscribers and a small number of other customers sharing the facility would receive the program and only the subscribers would be able to decode the program. The great majority of customers would not have the switched service routed to their TV sets.

What would be the motivation for supporting switched video? Broadcast services are based on the proposition that a large base of customers desire the service. By contrast, switched video would be more appropriate when the service is requested by a single customer (an obvious example would be individual customers requesting titles from a video library).

Time has a way of presenting new options to provide the means to an end, or making moot the entire need for the end. In the mid-1990s many service providers were contemplating building cable networks that incorporated switched-video services for several reasons, including the requirement to allow independent video information providers to reach customers on the network, to allow true video on demand service, and to allow VCR-like controls on the video program. Since then, the regulatory environment for networks open to video information providers has

collapsed, customers have accepted near -Video-On-Demand (VOD) (saving the need for true VOD for the non-mass-market video service), and the VCR-like control has been implemented in personal video recorders owned by the customer (this function may soon be incorporated into the set-top box). While the need to deliver switched video has faded, the need to deliver digital data, which shares some of the same attributes as video, is more important than ever.

#### 4.4.1.1 Analog Video

Analog video signals are collected from satellite dishes and off-air antennas at a headend. Each video signal occupies 6 MHz and is NTSC compatible. The video signals are frequency shifted or modulated onto an assigned channel and combined into one signal ranging in frequency from 54 MHz to typically 750 MHz. Analog video is the basic staple of cable TV service.

Cable TV was first predicated on the ability to provide a clear high-quality picture to customers with poor over the air reception. Cable evolved to include satellite-delivered services. Originally these satellite channels were transmitted in NTSC format and indeed many widely distributed channels are still “on the bird” as NTSC. Increasingly to deter home satellite users and to provide a more robust signal, even these signals are transmitted in digital form to the headend. Is this digital video? Not to the customer. The program originator (HBO for example) transmits a digitized NTSC signal to the satellite, and the satellite transponder translates and sends the signal to the earth station or TVRO antenna. At the cable headend, the digitized NTSC signal is finally converted to analog NTSC for distribution to the customer. Analog video is analog before and after the set top box.

#### 4.4.1.2 Digital Video

The term digital can be as ambiguous or misleading as the word premium or turbo. An analog signal is an infinitely valued representation of something. In a TV signal there may be the signal voltage that represents the brightness of a given spot on the camera lens. This voltage is used at the TV receiver to reproduce the brightness of a corresponding spot on the screen. It is analog because that voltage may take any of an infinite number of values between 0 and 1 volt. (The system will try to respond to the small difference between 0.10 and 0.10001 and 0.1000014309 to the best of its ability.) That is an analog signal. In the case of a digital signal, one of a smaller set of numbers is used to describe the brightness of that spot. For argument sake the proper choices are limited to 0.10, 0.105, and 0.11. That is a digital signal.

Separate is the notion of digital transmission. The analog signal can be carried by analog transmission. In that case the transmission system will have to take care to maintain the relative differences between the signal values at different instants. In a digital transmission system, the only requirement is that the correct value is ferried across the system, which is the value 0.10. Confused? Well remember that an analog signal such as NTSC can be transmitted by an analog system or by a digital



system. Also, advanced modulation schemes such as 64 **Quadrature Amplitude Modulation (QAM)** or **16 Vestigial Sideband Modulation (16-VSB)** are designed to carry lots of digital signals using analog carriers.

#### A. Digital NTSC Video

Digital video is transmitted from the headend to the drop as a digital signal. There is a distinction between the kind of digitizing schemes used between the program originator and headend or on the super trunks. In general, the digital video delivered to the headend has not been compressed or is lightly compressed.

Digital compression is a vast topic and cannot be adequately summarized here. Signal compression is the act of reducing the bandwidth of a transmitted signal. The aim is to reduce the amount of redundant or unobservable information in the signal at the lowest cost in terms of the intelligence of the signal. Up to a certain point, most signals can be compressed by smart coding of the redundant information. For example, there is a lot of redundant information about how the letters of the alphabet look in print. Using morse code, one could read a typed letter, transmit the information to a distant receiver, and have a typewritten letter reconstructed at the other end.

At some point, a limit is reached in compressing a signal by only reducing the redundant information. To achieve a higher degree of compression, the schemes must begin to throw away or estimate certain information. The pre-headend digital transport is of very high quality and uses relatively low compression. By contrast the cable network digital compression can be quite high and the resultant signal quality is not as good. Why? There are several reasons.

The transport on the other side of the headend is shared by many customers, so a more expensive approach can be taken, because the cost is shared by many customers.

The transport on the access side of the cable network is bandwidth limited. Even 750 MHz or 1 GHz has its information capacity and will fill up with services.

The TV picture reconstructed at the set top box does not have to be perfect. By comparison, none of the analog signals at this point in the network is unimpaired relative to the original studio or even the headend quality. The cost to deliver a studio quality signal to the customer would be prohibitive.

#### B. Digital TV or HDTV

The analog TV broadcast system used in the United States transmits signals as an electronic wave. The electronic wave represents images and sounds by continuously changing frequencies and voltage levels. The transmitters then broadcast this signal over the air, and the electronic waves are translated back into images and sounds by TV sets. The transmitted wave is prone to degradation and interference over the air.

With digital TV, however, the transmitted signal (images and sounds) is divided into tiny components of computer information, the ones and zeros of computer language. This makes the signal more consistent and highly resistant to

interference. Digital TV sets receive this data and decode it back into images and sounds. This results in a perfect, studio-quality picture that is free from the interference, snow, and ghosts that appear on analog TV broadcasts.

Contrary to the prevailing trend of auctioning over-the-air frequency, the FCC has given the existing United States broadcasters a new High Definition Television (HDTV) spectrum in exchange for the return of the existing VHF or UHF spectrum by 2006.

The motivation for HDTV came from wide screen movies. After the introduction of the wide screen, it was discovered that individuals seated in the first few rows enjoyed the presentation in a way not typical in the conventional movies. The **Availability** digital TV standard adopted by the FCC in 1996 contains 18 scanning formats, six of which are for HDTV. These formats include interlaced and progressive scan HDTV and Standard Definition Television (SDTV) formats with varying frame rates, and two aspect ratios. SDTV is a digital TV format that provides a picture quality similar to that of a Digital Versatile Disk (DVD).

The following parameters determine the breakdown of the formats:

- *Active Lines of Resolution*: Scanning formats are measured in the horizontal and vertical active lines of picture elements or pixels transmitted. The total number of pixels is obtained by multiplying the number of vertical lines by the density of horizontal picture elements.
- *Aspect Ratio*: This is the ratio of the width to the height of the screen. Today's standard analog TV sets have an aspect ratio of 4:3 (16:12), which looks more like a square. Digital TV however, has an aspect ratio of 16:9, wide screen, and appears rectangular. This is the same ratio as movie screen and gives a more fulfilling viewing experience as in the movie theater.
- *Scanning Method*: Two scanning methods are defined - interlaced and progressive. Interlaced is when two fields, each containing half the lines, are broadcast and are later merged to form one complete picture or frame. Progressive is when all the lines are transmitted together without interlacing. Interlaced scanning (also used in today's analog TV) is indicated by an "i" in the video format, it fills in the odd number lines (1,3,5,7...) and then fills in the even number lines (2,4,6,8...) until the frame is complete. Progressive scanning, which is indicated by a "p", fills in each line consecutively until the frame is complete, like a computer display. Interlaced scan is preferred for transmission as it requires less bandwidth, while progressive scan provides the greatest definition.
- *Scan Rate*: Also known as picture rate or frame rate. This is the speed at which the lines are scanned before video frames are created. The scan rate is 60 or 50 fields per second for interlaced, 30 or 25 frames per second for interlaced, and 24 frames per second for film style progressive scan.

The most popular HDTV are 1080i 30, 720p 60 720p 30, and 480p 60, where i is for interlaced, p is for progressive, and the last number is the number of frames per second. The first number refers to the number of scan lines with the largest number

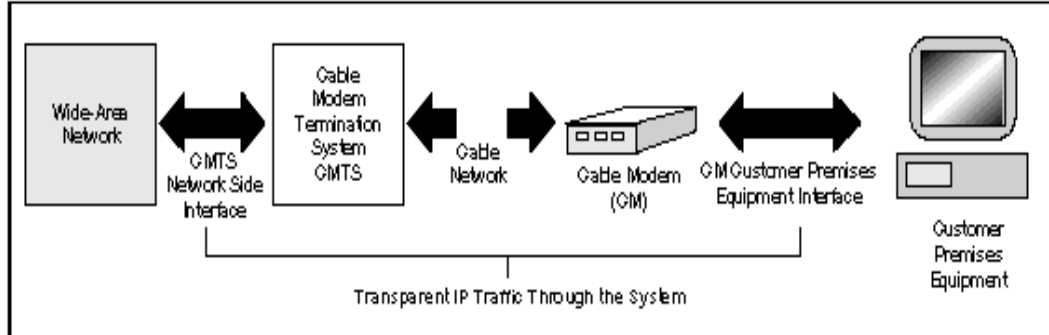
representing the highest picture resolution. 1080i requires about 3 times the bit rate to transport 480p, where 720p is in between with 30 frames logically requiring half the bit rate of 60 frames per second.

HDTV can be delivered to the home through the air, satellite, and cable networks. Broadcasters and cable operators have recently come to an agreement on which formats to use to transport the local ATSC video on cable networks.

#### 4.4.2 Data over Cable

The rising demand for high-speed data services to the home has led to the need to use the cable TV network to provide these services. Also there was a need to have interoperability among equipment from different vendors. To achieve this goal in a timely manner, CableLabs and several multiple system operators (MSOs) decided to create a set of interface specifications that allows “the early definition, design, development and deployment of data over cable systems on a uniform, consistent, open, non-proprietary, multi-vendor interoperable basis.”

A service goal was established indicating that this intended service will allow transparent bi-directional transfer of **Internet Protocol (IP)** traffic, over an all-coaxial or **Hybrid Fiber-Coax (HFC)** cable network. The simplified form of this goal is depicted in **Figure 4-10**.

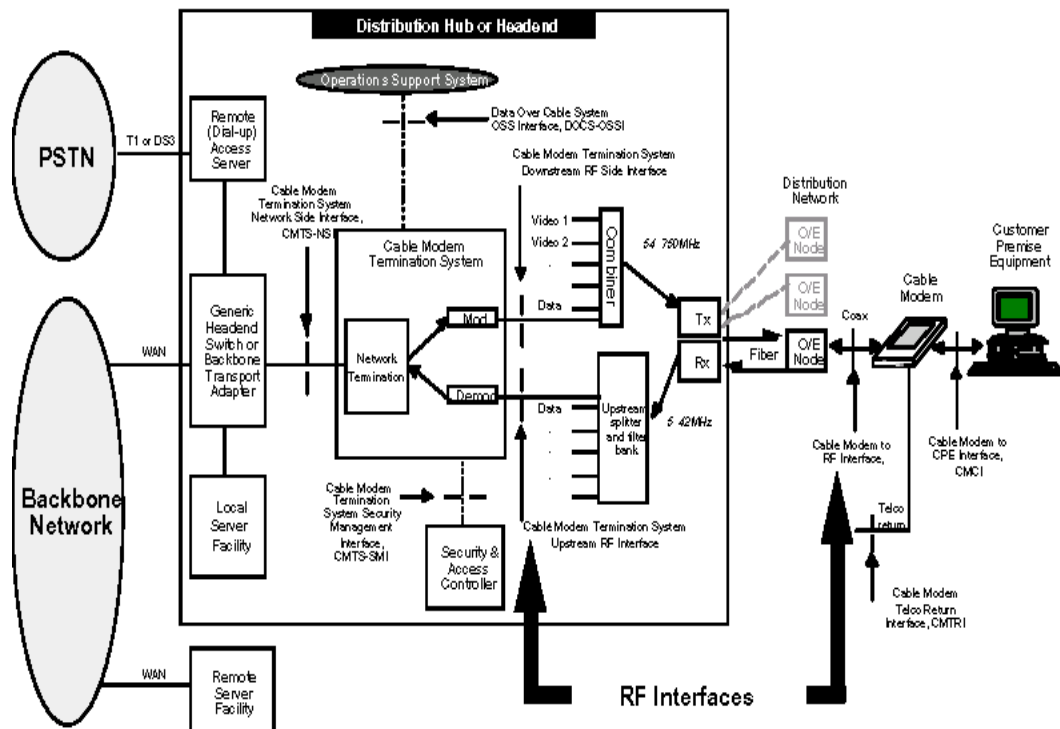


**Figure 4-10** Transparent IP Traffic Through the Data over Cable System

The **Data Over Cable Service Interface Specification (DOCSIS)<sup>TM</sup>** (originally discussed in **Section 2**) was created to ensure interoperability among different vendor equipment. DOCSIS provides the framework that governs the transmission of packets over cable networks by ensuring that data packets are correctly routed. The first version of DOCSIS did not provide for the **Quality of Service (QoS)** and security features. The enhanced version, DOCSIS 1.1, includes extensions to the **Media Access Control (MAC)** layer protocol that provides the QoS and security features. This enables enhanced services such as Voice over IP and Video over IP to be offered over the cable TV network and provides differentiated levels of service

for applications such as e-mail, web browsing, etc. DOCSIS 1.2 will include extensions to the physical (PHY) layer protocol.

The reference architecture for the data over cable services and interfaces is shown in **Figure 4-11**. The cable data system consists of a **Cable Modem Termination System (CMTS)** and multiple subscriber modems, which are all connected by a cable TV plant. Depending on the plant layout, the CMTS can be located in the headend, distribution hub, or any other suitable location.



**Figure 4-11** Data over Cable Reference Architecture

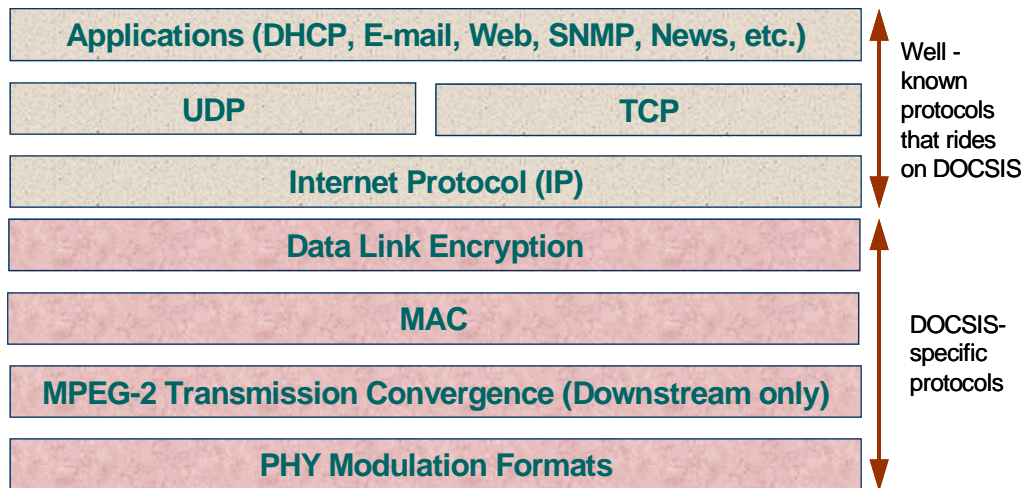
The reference architecture defines five different interfaces, as follows:

1. *Data Interfaces:* These consist of two interfaces: the cable modem to the **Customer Premises Equipment (CPE)** interface (CMCI in the figure) (between the customer's computer and the cable modem), and the **Cable Modem Termination System (CMTS)** Network Side Interface (NSI) (between the CMTS and the data network).
2. *Operation Support Systems Interfaces:* These consist of network element management layer interfaces between the network elements and the high-level operations support systems, which support the basic business processes.

3. *Telephony Return Interfaces*: This defines the interface between the cable modem and a telephone return path (CMTRI), in situations where the return path is not through the cable network.
4. *RF Interfaces*: These define the RF interfaces between the following:
  - Cable modem and cable network
  - The CMTS and the cable network in the downstream direction
  - The CMTS and the cable network in the upstream direction
5. *Security Interfaces*: This defines the baseline data-over-cable security.

#### 4.4.2.1 DOCSIS Protocol Stack

The protocols that are defined and adopted for DOCSIS address modulation schemes up to the networking protocols. These protocols all have specific functions; the relationship among these functions is presented in the DOCSIS protocol stack, as [Figure 4-12](#) depicts.



**Figure 4-12** DOCSIS Protocol Stack

The lower four layers are present only between the modem and the CMTS over the cable network, and these protocols are unique to the cable data networks. The higher-layer protocols are carried by the DOCSIS-specific layers and are used for Internet communications. When the cable modem receives IP packets from the host CPE, it adds the data link encryption and mediates access to the return path. It then modulates the data onto the cable network.

The following is a short description of the four lower layers in the protocol stack:

- The PHY includes the modulation schemes used on the coax network. These are 64- and 256-QAM on the forward and **Quadrature Phase Shift Keying (QPSK)** and 16-QAM on the reverse.
- The **MPEG-2** transmission convergence (TC) layer (downstream only) means DOCSIS modem data is encapsulated in 188-byte MPEG-2 frames. This allows modem data to be multiplexed with other MPEG streams on the same forward path RF carrier. An example would include sending MPEG-2 video and audio on the same carrier as MPEG-2 encapsulated DOCSIS data.
- The **Media Access Control (MAC)** layer controls modem access to the return path. Because there may be many modems trying to transmit simultaneously on the return path, the MAC protocol provides an orderly method for the CMTS to tell a modem when it can transmit and for how long.
- The data link encryption layer provides security for the user data. Encryption is needed because the cable network is shared and there must be a method to protect user data from malicious users.

#### 4.4.3 Analog Voice over Cable

The HFC network is a flexible access and transmission system that could be leveraged to deliver analog voice services to residential customers. With the market for local and long distance telephony services estimated at over 70 billion dollars a year, the market for telephony services is significantly larger than that for video. The HFC network is an affordable way to capture a piece of this profitable market.

This new telephony market is unregulated and the key competitive issues include availability, reliability, cost of service, and bundling of services.

The HFC has a number of advantages over other media in delivering analog voice services. These include the use of the existing infrastructure to provide the service at very little cost. It also affords the cable operators the opportunity to bundle analog voice service with other services.

Due to the stringent requirements of voice conversations, there are challenges that need to be overcome to provide a toll-grade voice service. First, there is a limitation on the amount of upstream bandwidth on HFC networks and this needs to be carefully addressed. The customer expects to get a dial tone when the receiver is lifted, so there must be sufficient bandwidth to meet the peak demand for two-way services. Although the bandwidth requirement for a single voice service is very low, the bandwidth requirement grows in proportion to the number of simultaneous calls. This is in contrast to a broadcast video service, which requires a large chunk of bandwidth but is not affected by the number of simultaneous users. Also the broadcast video service does not require upstream bandwidth.

Telephony is a lifeline service with an availability requirement of 99.999 (called **five-nines**), so QoS is an issue that needs to be addressed. Telephony has a variable QoS requirement depending whether it is carrying data or voice. The HFC network was designed originally to carry broadcast video, which can tolerate some

inaccuracy, but is very sensitive to stream interruption because of its real-time attribute. Voice is a real-time application that is intolerant to delay, but tolerant to some inaccuracies. Conversely, data can tolerate some delay, but requires a great deal of accuracy. The cable operator planning to offer analog voice service on the HFC network must ensure that adequate QoS guarantees are provided.

Another issue of concern is powering for telephony service on the HFC network. Telephones require power from the network unlike TV sets or set-tops. Unlike coaxial cables, which can carry both power and a signal, fiber cables can only carry a signal. So telephony service over an HFC network requires that power be inserted at the optical nodes, where the network becomes coaxial cables. The power can be generated remotely and transported to the optical nodes or generated at the optical nodes.

As the power travels from the optical node toward the home, there is a voltage drop due to loop resistance. If the voltage drop is significant, the remaining voltage might not be sufficient enough to power the devices in the network. Solving this problem is not as simple as just increasing the voltage to compensate for the loss because components such as taps and splitters have a limit on the amount of power they can carry without suffering damage. There is also a need for battery backup to support service in case of power failure. Backup is required for telephony due to support for critical lifeline services such as E9-1-1 services.

#### 4.4.4 Digital Voice over Cable

Voice over cable telephony falls under the broad category of voice over packet, implying that the challenges facing the cable operators are very similar to the challenges telecom operators face in delivering voice over **Asynchronous Transfer Mode (ATM)** and **Frame Relay** networks. Unlike ATM and Frame Relay networks, which are targeted toward the enterprise community, cable is targeted toward the home. Since cable is ubiquitous in most residential areas, the infrastructure investment is greatly reduced.

The traditional cable TV system is only capable of downstream transmission (headend to subscriber), not upstream transmission. Communications from the subscriber to the headend is possible with the use of a telephone line. But with the demand for integrated voice, data, and video services, cable operators have invested to upgrade their existing buried cable infrastructure from half duplex to full duplex.

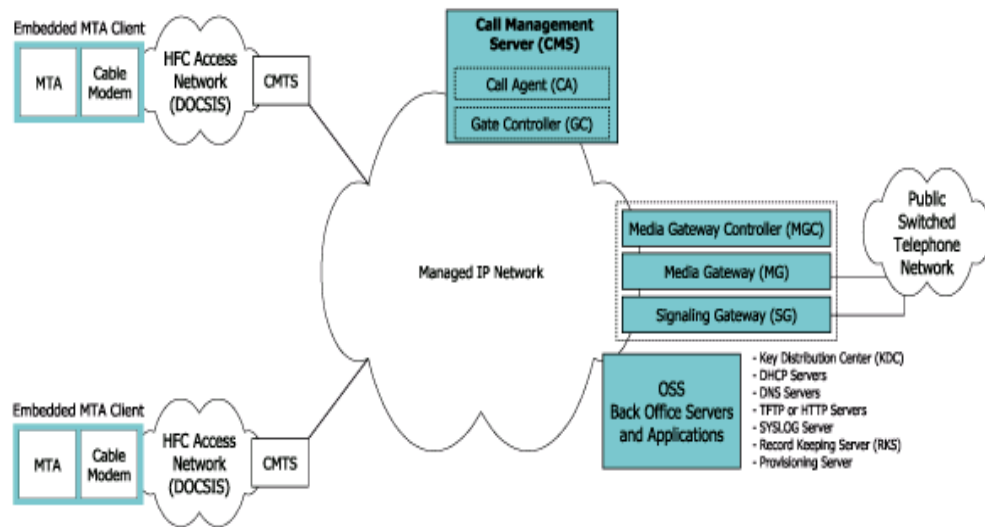
**Plain Old Telephone Service (POTS)** is a **Point-to-Point (P-P)** communications system that provides a dedicated channel to voice traffic between two end points. The traditional cable system is a broadcast system that carries the same information from one point to multiple destinations, and it has no mechanisms that support the QoS required by voice traffic. To support IP telephony in the cable network, there is a need for enhancements to the existing network. The cable network should be able to provide a direct connection between two telephones, i.e., the callers expect to send and receive only their voice packets. Also, the voice packets must be given

higher priority over data packets and the quality of the call must be comparable to that of POTS.

DOCSIS 1.0 provided the framework that governs the transmission of packets over cable networks by ensuring that data packets are correctly routed. That version, however, did not provide for the QoS and security requirements for voice traffic. The enhanced version, DOCSIS 1.1, does.

DOCSIS 1.0 also did not provide for the signaling for voice calls. A DOCSIS 1.1 network with PacketCable extensions enables cable operators to deliver data and voice traffic efficiently and economically using a single high-speed, QoS-enabled broadband architecture. The PacketCable specification known as the Network-based Call Signaling (NCS) protocol was created by CableLabs® to provide the signaling for voice calls over cable networks. NCS is based on the existing **Media Gateway Control Protocol (MGCP)** and uses network-based call agents to set up cable-based IP telephony calls.

**Figure 4-13** shows the reference PacketCable architecture. The architecture defines what is known as a “SoftSwitch” architecture for **Voice over Internet Protocol (VoIP)**.



**Figure 4-13** PacketCable Reference Architecture



The core set of PacketCable specifications describes how to move the basic functions that are typically consolidated on a single, expensive Class 5 **Central Office (CO)** switch onto several general-purpose servers. This has the advantage of a low-cost, highly flexible, scalable, and distributed architecture. The PacketCable architecture is flexible and can be extended to support advanced real-time multimedia services, such as multi-person game playing, video conferencing, etc.

The multimedia terminal adapter (MTA) provides these services on top of the IP and may either be a separate device or embedded within the cable modem as **Figure 4-13** shows.

#### 4.4.4.1 Billing Considerations

Billing must be considered when it comes to providing telephone service over cable networks. Traditional cable TV customers pay the same charges every month and there is no need for metering or monitoring the customer's usage except in cases of pay-per-view or other specific requests.

Telephone billing entails a different kind of approach, requiring customers to pay a monthly recurring fee and, in addition, the customer pays for local, long distance, international, and premium services based on usage. Call agents and broadband telephony interfaces (BTIs) are required to collect all the usage information. BTI is the cable version of the phone box that is normally located outside every home. If a BTI is not available, a voice-enabled cable modem in the customer's house can be used to deliver telephony service over cable.

#### 4.4.4.2 Challenges of Providing Toll-Quality Service on Cable Networks

To provide toll-quality telephony service, voice packets need to overcome a variety of obstacles inherent in packet-based networks. IP networks move packets on a best effort basis and there is no concept of quality of service. The obstacles that need to be addressed to provide toll-quality service on cable networks are discussed below.

##### A. Latency, Echo, and Jitter

The term **latency** refers to delay that packets experience as they travel from one point to another in the network. The delay of packets in the network could result in **echo** and talker overlap. Echo occurs when the voice signals are reflected back to the speaker and it is noticeable when the delay is more than 50 milliseconds. Echo cancellation mechanisms need to be implemented to solve this problem. In the traditional POTS network, echo is normally originated from the telephone network toward the packet network. An echo canceller uses a digital adaptive filter to set up a model or characterization of the voice signal and echo passing through the echo

canceller. The echo canceller compares the signal from the telephone network and the removes the echo on the transmit path into the packet network dynamically.

Talker overlap becomes a problem if the one-way delay is more than 250 milliseconds. The solution to this problem is ensuring that the delay is minimized as much as possible.

The contributors to latency in a VoIP network include accumulation delay, algorithmic delay, processing delay, network delay, and polling delay.

- Accumulation delay is due to the need to collect a frame of voice samples to be processed by the voice coder. This varies from a single sample time to many milliseconds depending on the **Coder/Decoder (CODEC)**.
- Algorithmic delay is the delay due to the inherent nature of the employed encoding algorithm.
- Processing delay is the delay experienced during the process of collecting and encoding voice samples into packets before transmission.
- Network delay is the delay experienced by voice packets as they travel through the network. The transmission physical medium and protocols are factors that contribute to network delay of voice traffic. Also, the **jitter** buffers that are used to smooth the jitter caused by irregular packet arrival times contribute to the delay.
- Polling delay is caused by the fact that the headend equipment needs to poll the BTI at each customer's location for voice packets because there is no dedicated connection with the BTI.

#### A. Lost Packets

The current IP network does not have a mechanism in place to differentiate packets from different applications with varying QoS requirements. All packets are given the same treatment. For example, if network congestion occurs, voice packets are dropped with the same probability as non-voice packets. Lost non-voice packets could be retransmitted in case they are lost, but this is not the case with voice packets because of the time sensitivity.

There are measures that VoIP software could take to mitigate this problem. Interpolation for lost speech packets is the first method. This is accomplished by replaying the last packet during the period the lost packet would have been played out. This scheme works well if packet loss does not happen frequently, but does not work well if a burst of packets or consecutive packets is lost. The second method is introducing redundancy through sending replicate packets, but this uses more bandwidth and has a tendency to introduce delay. Also a lower-bandwidth voice coder could be used to provide redundancy, which reduces the problem of bandwidth usage, but does not eradicate the delay problem.

#### 4.4.4.3 Fax over Cable

Sending a fax over a packet network such as a cable modem network combines the flexibility of a traditional fax with the convenience and cost-efficiency of a packet network.

The issues associated with sending voice over cable outlined in this document are also applicable to sending fax over cable networks. The most significant of these issues are timing and lost packets. The fax protocols require precise timing of packets and any delay of the fax packets could cause the timing to be skewed, which could lead to loss of the call. The fax over packet protocol is expected to compensate for this problem. Lost packets cause more problems in fax transmissions than in voice transmissions. With voice transmissions, packet loss is compensated for with one or more of methods discussed in the previous section. But the fax over packet protocol can fail if packets are lost.

#### 4.4.5 Interactive Services

Interactive TV services can be provided through the cable modem, and can feature high-speed Internet and web access through the TV set or PC. The earliest form of interactive TV was the remote control to change the channel or adjust parameters such as volume, color, brightness, etc.

According to Whatis.com, interactive TV services means allowing the viewer to interact with the TV set in ways other than simply controlling the channel and the volume and handling videotapes. Interactive services should not be confused with on-demand services (e.g., video-on-demand). Typical interactive TV services include electronic mail, home shopping, home banking, network games, and voting, which require provision of some immediate feedback through the TV connection. These services use the cable system as a two-way communication system.

On-demand services are similar to interactive services, but they provide a dedicated video and audio stream to the customer through the cable system in addition to employing the cable system for two-way communication data services. Typically the QoS requirements for interactive services vary from those of on-demand services.

**Table 4-1**<sup>1</sup> compares these requirements. On-demand services are discussed in **Section 4.4.6**.

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1. Taken from OpenCable Architecture by Michael Adams, Cisco Press 2000

**Table 4-1** Comparison of QoS Requirements for Interactive and On-Demand Services

QoS	Interactive	On-Demand
Bit Rate	20 to 200 Kbps	2 to 6 Mbps (standard definition)
Delay	Variable	Constant
Loss	$10^{-6}$	$10^{-10}$
Error	$10^{-6}$	$10^{-10}$
Retransmission	Allowed	Not Allowed

Interactive TV involves adding a special “set-top unit” to the existing TV set. In addition, other installation and infrastructure arrangements are required, depending on the particular approach. Interactive services can be grouped into the following categories:

#### *Navigation Services*

These are services that are usually packaged together and include

- Analog and digital tuning
- Interactive program guide
- Impulse pay-per-view interface
- VCR remote control
- Parental control
- Subscriber preferences and configuration
- Digital music service
- Emergency alert system.

Pay-per-view programming is used to describe services for which the customer pays an additional amount, after the basic subscription fee, for specific programming. The user gains access to the movie with the use of the remote control.

#### *Information Services*

This category cover services in which the customers know the kind of information they need and they want to access it immediately. Such information includes news, sports, weather, stock reports, etc. Information services can be tailored to individual customer preferences or according to the area the cable system serves. The information can be displayed with text and graphics and could become available at any time the customer is watching TV.

### *Communication Services*

Communication services include electronic mail, chat-rooms, IP telephony, and video conferencing, and they usually require some type of additional hardware such as a wireless keyboard.

### *Electronic Commerce Services*

These services include home shopping and home banking, which may provide the capability to withdraw electronic cash from a bank account through the set-top. The digital set-top could also be used to verify electronic transactions because of its sophisticated digital security system.

### *Video Games*

These kinds of services require a high CPU performance and graphics support, which are easily supported by dedicated game consoles because of their highly optimized architecture for dedicated game playing. But it is still possible to provide quality support for older, classic video games and educational video games. Because some games require more memory than is available in the digital set-top, a proposed solution is to break them into levels that are downloaded as the player progresses through the game. In the case of a network game, where a player is playing against other players in a network-shared game space (game server), the cable system is used to establish a two-way link to the game server.

### *Enhanced TV Services*

These types of interactive services offer the mix of the TV model, where the user is completely passive, and the PC model, where the user is usually active. This is realized by giving the TV viewer an interface to an interactive session at predefined spots during the TV program. This could be in the form of enhanced TV commercials, which allows the customer to express interest in a TV commercial as it is playing. During the commercial, an icon appears that indicates it is an interactive commercial and the customer could express interest in the product by pressing a button on the remote control. Then the customer is provided with more information about the product. Another flavor of enhanced TV services offers the capability to play-along with a game show; the customer can participate with the TV contestants and the set-top box keeps track of the score, which may be transmitted to the programmer. Enhanced TV services also allow customers to participate in opinion polls and surveys, which are reported instantaneously to the programmer.

Some implementations of interactive TV are discussed below.

#### 4.4.5.1 Web on the TV

This service is provided with servers that are linked to the cable TV or telephone company plant. The servers package the Web content and deliver it to the TV set, which requires reformatting the text and graphics so that they fit onto the TV sets. This is required because the size and resolution of the TV set is different from that of a PC. The user can switch between the TV and the Internet at the touch of a button. However, in some implementations, the TV shrinks to a small corner on the screen while the user is on the Internet.

A good example of this product is the Microsoft's WebTV. This allows the user to view web pages with a WebTV's browser and a handheld control while using the TV set as the display device. A wireless keyboard is optional. The subscriber has to buy a set-top box and then sign up for Web access. WebTV enables the user to play along with game shows, participate in polls, send/receive electronic mails, and chat with other viewers during Interactive TV programming. WebTV also allows the user to pause live TV and instantly replay favorite scenes.

Other services such as Wink gives the user the interface to request more information about products featured in advertisements. Wink is a free service that gives companies and advertisement agencies a new avenue to market their products and services via Interactive TV. Other services like ACTV also allows instant replay of live TV and give several camera angles during a program such as a sporting event. ACTV also allows the user to customize the content and advertisement that would be delivered to the TV set. Two families may watch the same program, but might see different advertisements based on the information stored in their set-top boxes.

#### 4.4.5.2 Personal Video Recording (PVR)

Personal Video Recording (PVR) services use a high-capacity hard drive to store incoming video signals. The recorded signals are then played to the user on request. This offers the customer the capability to pause and rewind live TV programming, as well as let the user program to record at the touch of a button. When the user is on replay, the system keeps recording the live action so that nothing is missed. Examples of products that offer PVR are WebTV, TiVo, and ReplayTV.

#### 4.4.6 On-Demand Services

On-demand services are similar to interactive services, but they provide a dedicated video and audio stream to the customer through the cable system in addition to employing the cable system for two-way communication data services. The most common example is Video-On-Demand (VOD). Other forms of on-demand services include music-on-demand, post-broadcast-on-demand, special interest (or niche) programming, distance learning, library access, and video mail.

#### 4.4.6.1 Video-On-Demand (VOD)

VOD is form of interactive system that is similar to cable TV with the main difference being that the user can select movies from a video database. Videos are digitized and stored in a server at the cable network headend. VOD allows the user to watch different programs or movies anytime, which makes it similar to a video rental except that the user would not have to leave the house to enjoy these services. When a movie is requested, it is streamed over the cable network to the user's set-top box, where it is processed before being displayed on the TV screen. There are three variations of VOD depending on the capabilities and features provided:

- *Quasi Video-on-Demand (Q-VoD)*: The subscribers are grouped and offered programming based on their interest. This offers very limited flexibility and control as a subscriber is only allowed to switch to another group, but there is no control over the kind of programming available to the group.
- *Near Video-on-Demand*: More flexibility than Q-VoD is allowed where functions such as forward play and rewind are simulated by transitions in discrete time intervals (on the order of 5 minutes). This functionality can be implemented by offering the same program on multiple channels, but are delayed in time.
- *True Video-on-Demand*: The subscriber has complete control over the programming. Functionalities similar those of the VCR forward/reverse play, slow motion, pause, and random positioning are offered.

#### 4.4.7 Electronic Program Guide

The Electronic Program Guide (EPG) consists of all the data necessary to tune channels and display available program information. It helps the user to navigate through a whole host of channels.

The **Availability** has specified a standardized format for transmitting information about current and future programs using private sections in a transport stream as defined in ISO/IEC

13818-1. The transmitted information can be collected and processed by special receivers to provide the user with an EPG. The format of the program guide is very flexible to address the varying needs of different broadcasters. A broadcaster controlling a single terrestrial channel might only send information about its own programs, while a closed network broadcaster such as cable TV or direct broadcast satellite operator might send a coordinated program guide for an entire group of channels. In a situation where a broadcaster only sends information about its program, a special receiver would collect the information from each broadcast channel and create a database that would support an EPG.

The EPG includes system information and control information such as system time, physical channel transmission channels, and additional program guide information. The EPG can also be used to keep a record of the kind of programs each family

member watches. It could gather enough information over a few months to advise the viewer that a most frequently watched programming is available for viewing or taping.

## 4.5 Integration with other Technologies

For cable networks to smoothly handle services that involve other types of data networks, the cable network must understand the protocols of the outside networks. Also, the use of standard protocols can result in lower-cost network equipment that shares the similar development costs.

This section takes a brief look at where some well-known transport technologies might be advantageously used within the cable network.

### 4.5.1 SONET/SDH

The **Synchronous Optical Network (SONET)** is an optical transport standard. It specifies rates, frame, and cell composition and other important technical details necessary for vendor compatibility and interoperability.

SONET establishes a family of optical line rates similar to the **DS1, DS3** hierarchy. Using this hierarchy, equipment can be ordered to operate at **Optical Carrier 3 (OC-3)**, 155 Mb/s, or OC-192 (almost 10 Gb/s). STS-3 and STS-192 are the corresponding electrical rates used with SONET. Related to SONET is the Synchronous Digital Hierarchy (SDH). SONET is the North American flavor of SDH. A distinct advantage of SONET/SDH is the inherent support of ATM features that make SONET/SDH links much more flexible from an arrangement point of view and easier to maintain.

Although the headend to subscriber link is analog over fiber then coax, there is a digital information carrier in the analog signal. The video trunking and back office data operations of the cable network can directly benefit directly from SONET/SDH.

### 4.5.2 Asynchronous Transfer Mode (ATM)

The **Asynchronous Transfer Mode (ATM)** is a sophisticated telecommunications technique for simultaneous transmission of voice, video, and data across a single broadband digital network. To describe ATM in great detail is far beyond the scope of this section. In short, it provides a means to organize data into cells, classify the cells according to a level of service desired, route the cells within the network, and guarantee delivery of the cells to the destination.

ATM was once thought to be too expensive for applications such as cable networks. Some still share this view. However, some ATM features are desirable enough to command consideration by network designers. By such means as permanent virtual



circuits and virtual paths, ATM is able to divide the various data “pipes” between network elements such as servers and routers and customer set-top boxes such that various customer activities are supplied with data at the appropriate rates and levels of service. For example, voice service is very intolerable of delay, even though it is relatively low in bandwidth. Video can be buffered to smooth out the variations in delivery of the cells bringing it to the customer. The data application programs use is the least likely to cause the user any inconvenience due to delivery variations. Thus, a set-top box using ATM could be configured in conjunction with a server to provide a guaranteed rate for the voice traffic, and separate virtual pipes could be used to connect other services. In this respect ATM can be very useful for setting up simultaneous sessions by different users (or the same user) with different needs.

### 4.5.3 Internet Protocol (IP)

The **Internet Protocol (IP)** has been extraordinarily successful in the last decade at allowing the interconnection of all types of disparate networks. Internet, which is short for inter-connected networks, is not a high performance network, as any user can observe, but there are private Internets that operate a very high level of service. One way to accomplish the level is limit the amount of traffic carried on the network. This is written to stress that a network using IP is not necessarily “the Internet.” What is there is the rules and tools for routing packets of different sizes to destinations.

IP is very popular with network designers because it works and is relatively inexpensive (especially in comparison to ATM). While ATM provides for different service levels, IP does not inherently provide this feature nor does it guarantee delivery of packets. Several add-on protocols are aimed at addressing these shortcomings, but one of the most popular methods remains to throw bandwidth at the problem. That is, by over-designing the network capacity, the statistical chance of not providing the needed service diminishes with the extra capacity provided for.

## 4.6 CPE Considerations

The **Customer Premises Equipment (CPE)** varies depending on whether the application is voice, video, or data. The following subsections describe the applicable CPE in a cable network.

### 4.6.1 Cable TV Set-top Converter Box

The **set-top converter box** is the electronics that connect a TV to the incoming cable TV signals. The primary purpose of the converter is to convert the midband and superband cable channels to the VHF TV channels than can be tuned on a TV receiver. A set-top converter box is needed to view cable TV signals unless the subscriber is using a cable-ready TV set. A set-top converter box could either be digital or analog depending on the incoming cable signal.

#### 4.6.1.1 Analog Set-top Converters

At first, set-top converters were used to give access to more channels because the early TV sets could not tune most of the frequencies that cable systems used. These early basic set-top converters performed basic remote control functions such as tuning, volume control, and channel number display. There are two basic types of analog converters: block converters and tunable converters.

Block converters provided a simple, inexpensive way for cable systems to increase channel capacity. They were employed in small cable systems that carry a few midband or superband channels. These converters have a two-position switch. When in the normal position, the subscriber can tune 12 TV channels on the receiver's VHF selector. In the midband position, seven different channels appear on channels 7 through 13 of the receiver's VHF selector. Another type of block converter shifts the midband or superband channels to the UHF band selector.

With tunable converters, the channel tuning is done with the converter and it is delivered to the TV receiver on a vacant VHF broadcast (typically channel 2, 3, or 4). The converter has a knob, slide, or a series of push buttons or keyboard used to select the desired channel. The functions that these basic converters provide are available on cable-ready TV sets, which makes these converters obsolete.

A de-scrambling set-top converter is a form of analog converter that can perform tuning as well as conditional access functions. The cable tuner selects a single 6 MHz channel and rejects all other frequency channels. The frequency is converted first to an intermediate frequency (IF) that is suitable for demodulation by an NTSC demodulator. Conditional access is the means by which access to specific services is granted to the user based on payment for those services. The services that the set-top is allowed to access must be programmed into it before it is installed in the customer's home.

Addressable converters also perform tuning and conditional access functions, but the services that the set-top is allowed to access are controlled remotely from the headend with messages sent to that particular set-top alone. More information on descrambling and addressability is in [Section 6](#) of this document.

An advanced analog set-top converter is a type of addressable set-top converter, which supports additional features such as an On-Screen Display (OSD), an Electronic Program Guide (EPG), and Impulse Pay-Per-View (IPPV).

#### 4.6.1.2 Digital Set-top Converters

A digital set-top converter converts the digital TV picture (e.g., HDTV) into an analog NTSC picture to allow for the use of existing analog TV receivers. Digital set-top converters can be classified into two major categories: basic and advanced.

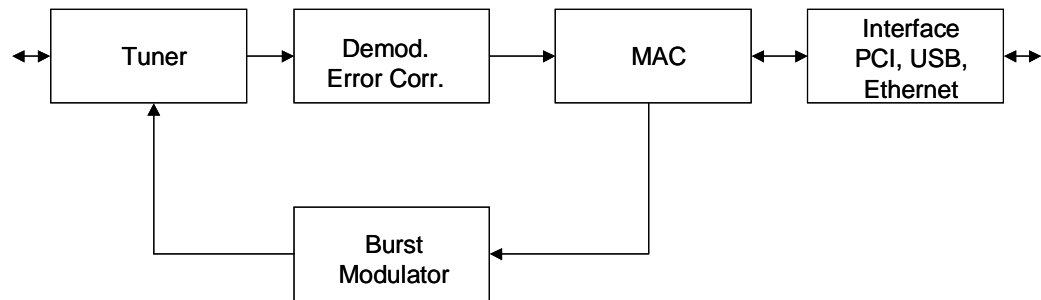
Basic digital set-tops perform functions such as tuning, demodulation, conditional access, and decoding. They provide a digital equivalence of advance analog set-top converter functions such as the EPG and IPPV for broadcast digital services.

Advanced digital set-top converters provide all the functions of a basic digital set-top converter in addition to supporting two-way, real-time data communications over the cable plant and more advanced applications. In fact, the digital set-top converter is actually a hybrid analog/digital set-top converter and has evolved directly from the advanced analog set-top. This is needed for the digital set-top to support all existing analog services, in addition to the new digital services. These new services include Personal Video Recording, Web on TV, and picture-in-picture viewing.

#### 4.6.2 The Cable Modem

A cable modem is a device that enables the cable network to deliver data and voice services to the customer premises. A cable modem can be integrated with a cable TV set-top box, or integrated into the PC, or can be an external stand-alone device. [Figure 4-14](#) shows the basic architecture of a cable modem.

The tuner connects to the cable TV outlet and it converts the TV channel to a fixed lower frequency (5 to 42 MHz). The tuner has a built-in diplexer, which is used to process both upstream and downstream signals through the same tuner. The demodulator is employed in the downstream direction and it performs analog-to-digital (A/D) conversion, demodulation, error correction, and MPEG synchronization.



**Figure 4-14** Basic Cable Modem Architecture

The **Media Access Control (MAC)** extracts the MPEG frames, filters the data for other cable modems, and provides the multiple access control among contending upstream transmissions. The burst modulator performs Reed-Solomon encoding, modulation frequency conversion, and digital-to-analog (D/A) conversion.

Typically, the cable modem attaches to a standard 10BASE-T Ethernet card in the computer. Also it can connect through interfaces such as a PCI bus (internal cable modem) or a Universal Serial Bus (USB).

An interactive set-top box is really a cable modem in disguise. An interactive set-top box provides a return channel - often through the ordinary **Plain Old Telephone Service (POTS)**, which allows the user access to interactive services such as web-browsing and E-mail directly on the TV screen. The return path could be through the cable plant in a two-way cable system.

## 4.7 Limitations and Issues of HFC

The HFC network architecture poses a number of potential problems even though it is more cost effective than most other access technologies.

The first of these problems is what could happen if there was a component failure in an amplifier in the distribution network. This could interrupt service to an entire neighborhood. Also, AC power failure is a concern because lifeline services such as telephony can now be offered on the HFC network. This was not a concern in the past because power outages meant no power for the remote equipment and the TV. Therefore, there is a need for backup powering for amplifiers and other equipment supporting any lifeline services.

Another issue with the HFC network is the shared upstream medium, which encourages attacks from malicious users. This is could paralyze the operation and communication of other users in the same branch of the HFC network.

Third, the transmission from the cable modem to the CMTS is highly prone to noise. This is related to the wiring in the customer premises network (CPN). The condition of the existing CPN depends heavily on when it was originally installed, the quality of the installation, and what modification and reconfigurations have been made by the home owner. Cable and connector performance can deteriorate with age, and older systems are likely to have been built with lower-bandwidth components and this could lead to significant loss in signal power.



## 5 Operations and Network Management

### 5.1 Cable Network Management

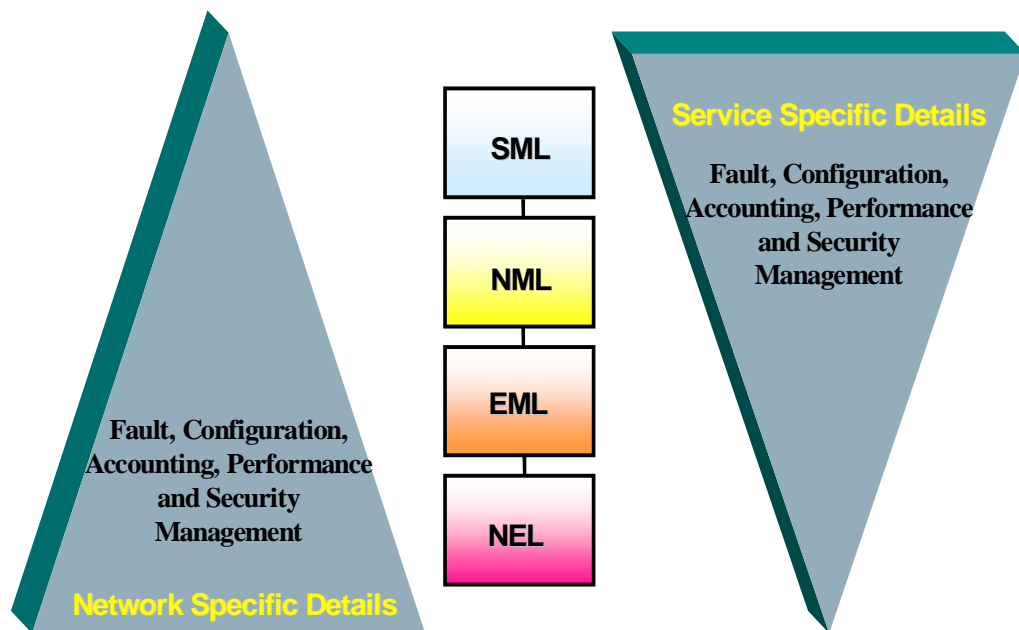
This section introduces the functions and requirements for managing a full-service cable network that provides all of the services described in [Section 4](#) (broadcast programming, voice, interactive video, pay-per-view, data). Although traditionally quite different from telecommunications management, cable network management is increasingly aligning with the best operations strategies of the traditional telephone companies. The telecommunications industry has defined a standard framework for network management called the **Telecommunication Management Network (TMN)** that applies well to full-service cable network management.

#### 5.1.1 Telecommunication Management Network (TMN) Overview

TMN provides a common view of the functions and data needed to manage telecommunications networks, ensuring interoperability among the hardware and software systems. It is a widely accepted standard industry practice for network service providers, network equipment vendors, and network management software suppliers to describe the functional domain of their products in the context of TMN.

TMN is an organized framework, not a requirement for how functions are physically placed in systems. A network management application architecture may use TMN functions to describe how vendor products satisfy the service provider's requirements, as well as how various products interoperate.

The TMN functional architecture describes and categorizes the functions that a TMN provides. The concept of logical layers in the TMN architecture is described in Clause 5 of ITU-T Recommendation M.3010. Logical Layering in TMN describes domains for functions ranging from network specific to service specific, and is shown in [Figure 5-1](#). This figure depicts that the amount of network specific details in each layer decreases from the Element Layer (EL) to the Business Management Layer (BML) while the service specific details increase from the EL to the BML. Some of the characteristics of each layer are described below.



**Figure 5-1** Logical Layering of a TMN Architecture

- **Business Management Layer (BML):** This layer includes goal setting; finance; budgeting; planning product definition; and agreements between jurisdictions (not shown in figure).
- **Service Management Layer (SML):** The SML layer includes service creation; contacts with customers and other service providers; selection and assignment of network resources for access to service; service usage measurements for billing; and **Quality of Service (QoS)** measurements.
- **Network Management Layer (NML):** This layer includes complete visibility of the whole network, nodes, and links; and the statistics and history pertaining to managed entities that span NEs.
- **Element Management Layer (EML):** EML covers the management of each NE on an individual basis; the control and coordination of a group of NEs; the gateway to NEs for the NML and higher layers; and the statistics and history pertaining to individual NEs.
- **Element Layer (EL):** The EL looks at the telecommunications functions of the resource components of NEs; the implementation of management commands; detection of problems; and autonomous activities.



Functions within a TMN may be categorized in a number of ways. Categorization of functions provides a method for identifying gaps within a TMN, and describing systems for flexible and modular deployment. Some of the ways functions in a TMN may be characterized include:

- Administrative Domain - Functions supporting management of customer networks, administration of core networks, or supporting administration of other carrier networks
- Technology Domain - Functions supporting a specific technology. For example: SONET, ATM, Frame Relay, IP, etc.
- TMN Logical Layer - BML, SML, NML, EML, and EL
- TMN Management Functional Areas (MFAs) - Fault, Configuration, Accounting, Performance, and Security (commonly known as FCAPS)
- Business Process Flow - Alarm correlation, Testing, Capacity planning, etc.

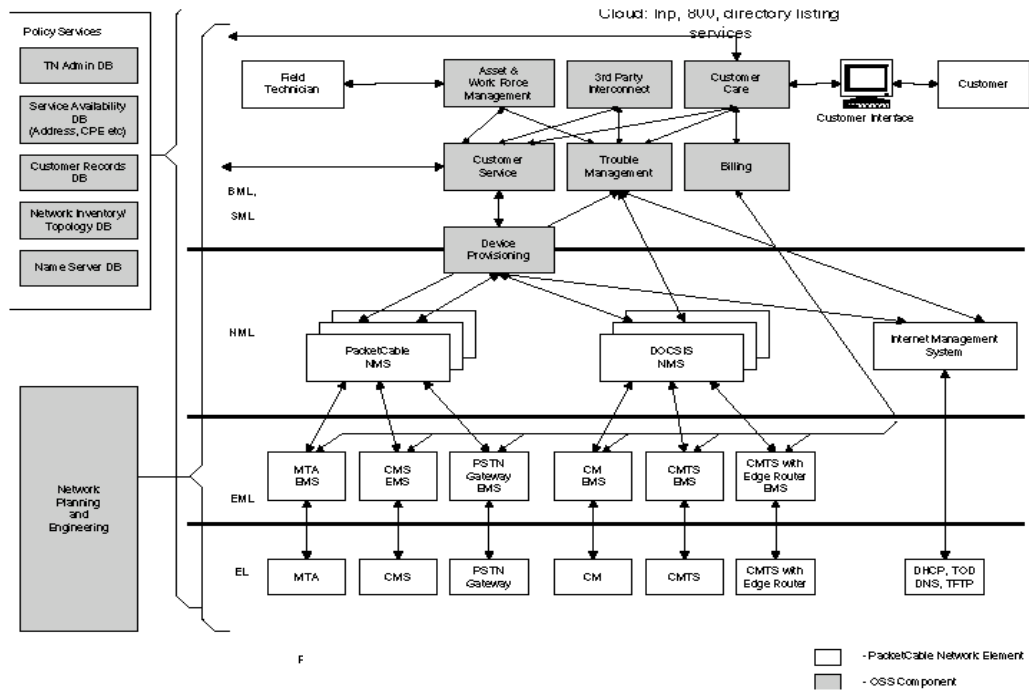
Using the TMN categories, the cable network management functions can be classified into the major functional areas shown in **Table 5-1**:

**Table 5-1** Cable Network Management Functions

Network Management Functional Area	Key Functions
Fault Management	<ul style="list-style-type: none"> <li>● Collecting network alarms and statistics</li> <li>● Handling customer trouble reports</li> <li>● Correlating alarms and determining root cause</li> <li>● Dispatching repair technicians and verifying service restoral</li> </ul>
Configuration Management	<ul style="list-style-type: none"> <li>● Building the network plant</li> <li>● Configuring network resources, including building assignable network inventory</li> <li>● Activating and deactivating customer service (including always-on and on-demand services)</li> </ul>
Accounting Management	<ul style="list-style-type: none"> <li>● Collecting network usage statistics</li> </ul>
Performance Management	<ul style="list-style-type: none"> <li>● Monitoring network usage and performance</li> <li>● Planning network upgrades to meet network utilization demand</li> <li>● Pro-active repair</li> </ul>
Security Management	<ul style="list-style-type: none"> <li>● Preventing unauthorized access to network services</li> </ul>

The traditional operations environment for the cable environment was centered around the billing system and had limited capabilities and limited flexibility. This environment is changing, however, as cable operators seek to support new data and voice services. For management purposes, the evolving cable network can be broken into several interconnected pieces for which there are management solutions:

- Management of the HFC access network including the **Host Digital Terminal (HDT)**, **Optical Network Unit (ONU)**, optical distribution network, coax terminations, and video broadcast and signaling channels across this network.
- Management of the customer data services, including the headend [**Cable Modem Termination System (CMTS)**] and modem (CM) devices that manage the customer's data service. In the CableLabs architecture (see **Figure 5-2**) this is referred to as the DOCSIS domain.
- Management of IP layer services, including **Dynamic Host Configuration Protocol (DHCP)**, **Domain Naming System (DNS)**, and **Trivial FTP (TFTP)**. In the CableLabs architecture (see **Figure 5-2**) this is referred to as the Internet Management System.
- Management of the customer packetized voice services, including: the Call Management Server (CMS), which provides signaling services used in voice communications; the Multimedia Terminal Adapter (MTA), which is **Customer Premises Equipment (CPE)** that contains the media interface to voice and/or video devices; and the **Public Switched Telephone Network (PSTN)** Gateway, which provides access from the cable subscriber network to the PSTN network.



**Figure 5-2** PacketCable Network Elements and OSS Components

- Management of video services, including signal management at the headend and customer service authorizations (e.g., pay per view credits).

The following sections introduce these domains.

## 5.2 HFC Access Network Management

The HFC architecture is described in [Section 4.3](#). HFC management capabilities are built on management requirements for **Fiber-In-The-Loop (FITL)** that are described in detail in Telcordia GR-909, *Generic Criteria for Fiber in the Loop Systems* (a general review of FITL is also in Telcordia SR-NOTES-SERIES-10). With the upgrade to an HFC network, cable providers will begin to rely on remote management tools to monitor and configure the network.

### 5.2.1 Fault Management

The HFC system will perform alarm surveillance of equipment and path failures and report this information to a remote management system. This includes detecting equipment alarms and correlating alarms to a root cause. Some of the fault conditions that the HFC system should report to an OSS include:

- Optical line failures (e.g., Loss of Signal or Loss of Frame) between the HDT and the O/E node
- Digital facility failures (e.g., DS1 or STS between the HDT and Class 5 switch or video backbone network)
- Failures on the RF signals between the O/E and the customer equipment
- Equipment failures at HDT, O/E, and customer network unit
- Power failure
- Environmental alarms (intrusion, climate control, and high water level).

### 5.2.2 Configuration Management

Configuration Management (CM) in general refers to all functions devoted to the management of physical and logical resources concerning customers, services, network structure, and the design and installation of network components (including equipment, facilities, software, and databases) supporting telecommunication networks.

For additional information on the management framework for CM functions under the TMN architecture, see also Telcordia GR-3010-CORE, *Configuration Management Based on the Telecommunication Management Network (TMN) Architecture*.

The cable operator will use the HFC's **Element Management System (EMS)** to manage:

- The configuration of transmission parameters for broadcast and switched video channels
- The subscriber signaling and control channels, which are assigned to a common RF channel on the cable distribution
- The HFC network software, including remote installation of new software releases and patches.

### 5.2.3 Performance Management

Performance monitoring is the systematic assessment of a particular entity's ability to carry out its assigned function through the continuous collection and analysis of performance parameters. Performance monitoring procedures are intended to capture intermittent error conditions and troubles resulting from the gradual deterioration of network equipment. Pro-active maintenance techniques such as performance monitoring enable the cable provider to do early detection of troubles before they escalate in severity. Indications of service affecting degradation are forwarded to Fault Management applications.

Performance monitoring of the HFC network involves the continuous, non-intrusive detection, collection, and reporting of traffic and/or protocol related events (traffic counts, counts of errors, logging of errors, etc.) at cable network interfaces and components. The HFC access system will collect, store, and report to an OSS transport performance data and report to the OSS when performance data thresholds have been crossed. Some of the performance capabilities that the HFC will have to support include:

- Reporting optical network performance data such as Code Violations (CVs), Errored Seconds (ESs), Severely Errored Seconds (SESSs), and Unavailable Seconds (UASs)
- Reporting performance data on ATM-layer broadcast and pay-per-view channels (e.g., ATM cells dropped)
- Performance monitoring of the connection between the subscriber and the headend (i.e., an RF carrier in the HFC access network)
- Collecting and store performance data
- Initializing performance data storage registers
- Setting thresholds for performance data threshold crossing events
- Reporting threshold crossing events.

### 5.3 Data over Cable Management

CableLabs has developed a reference architecture and management standards for high-speed data-over-cable systems developed by the CableModem (formerly DOCSIS) project of CableLabs (see [Figure 5-3](#)). This reference specifies the managed objects and the management communications protocol. It includes several documents that define management requirements and interfaces for the components of the data over cable architecture.

- The managed objects are defined in [Simple Network Management Protocol \(SNMP\)](#) Management Information Bases (MIBs). These documents define MIBs for the management of DOCSIS.
- Radio frequency interfaces (between cable modem and the cable network in the downstream and in the upstream direction)
- Baseline Privacy Interface (SP-OSSI-BPI)
- Telephony return interface (between the cable modem and a telephone return path, for use in cases where there is no RF return path in the cable network).

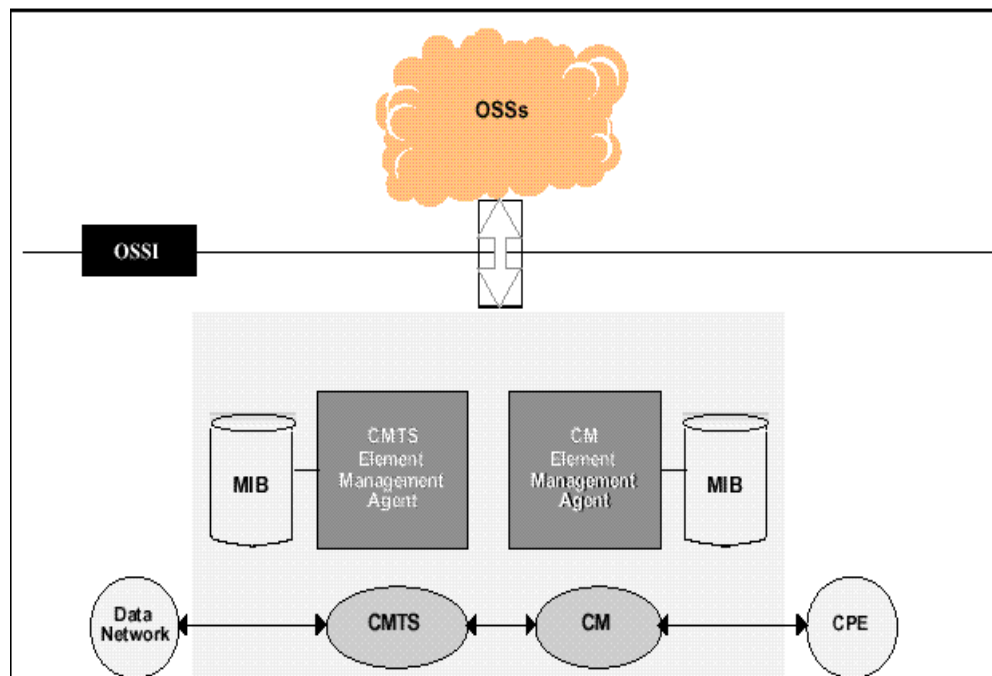


Figure 5-3 CableLabs Data over Cable Reference Architecture

## 5.4 Packetized Voice over Cable Management

Providing voice service to cable customers requires the addition of new functionality in the customer's cable modem. This Media Terminal Adapter (MTA) function contains the interface to a physical voice device, a network interface, CODECs, and all the signaling and encapsulation functions required for **Voice over Internet Protocol (VoIP)** transport and class features signaling.

The Society of Cable Telecommunications Engineers (SCTE) has published requirements for management of voice over packet cable service. SCTE DSS 00-1, *IP Cablecom Management Information Base (MIB) Framework*, defines a management framework for the MTA, which includes the following:

- Parameters for MTA device provisioning over the cable network
- Security certificates and signatures for the security handshake between the MTA and the provisioning server
- Management of configuration parameters such as provisioned bandwidth, physical voice port description, and signaling protocol

In addition to managing new functionality at the MTA, the cable provider will need to manage the GR-303 interface (described in the Telcordia document GR-303-CORE, *Integrated Digital Loop Carrier System Generic Requirements, Objectives, and Interface*) to the **Public Switched Telephone Network (PSTN)** at the **Cable Modem Termination System (CMTS)**.

Telcordia GR-3055, *Voice over Packet NGN Access Gateway Generic Requirements*, provides a management framework and the requirements for managing this interface.





## 6 Cable Network Security

As with all access technologies, security is a very important concern when it comes to cable networks. The introduction of value-added services has given rise to new forms of attacks because of the inherent vulnerabilities of the systems that support these services.

Similar to any other personal or commercial property owners, cable network operators must protect their equipment from physical threats such as outsiders tampering or stealing network equipment. Equipment damage not only leads to capital loss, but it also results in loss of revenue as services are interrupted, or even potential loss of customers as subscribers seek more secure alternatives.

Measures against these physical threats are relatively straightforward as they occur in predictable locations. Potential settings for physical security issues include the **Central Office (CO)** (or the **headend**), the transmission network (both optical and electrical), the access-drop junction, O/E nodes, and **Customer Premises Equipment (CPE)** sites. Solutions to physical threats typically involve restricted access of some sort, such as closed cabinets, locks, video surveillance, etc.

Detailed requirements on the security of networking equipment can be found in the Telcordia document, GR-1332, *Generic Requirements for Data Communication Network Security*. This section discusses the issue of cable network security as it relates to video, voice, and data services.

### 6.1 Video Services Security

Cable subscribers have the option of selecting a variety of video services. There is a foundation (basic) service required of all subscribers. The basic service consists of off-air channels, some distant channels, and some satellite-delivered programs. The cable TV provider often offers one or more specialized channels known as pay TV or premium channels at an additional fee. These premium channels are optional and there must be some way of preventing unauthorized viewing of programs offered on these channels.

The methods of preventing unauthorized viewing of individual channels range from simple filtering schemes to remote-controlled converter/descramblers. The following subsections present these schemes.

#### 6.1.1 Filtering

Filtering, which is also known as trapping, has two types of trapping mechanisms: *positive* trapping and *negative* trapping.

In the positive trapping mechanism, a jamming signal is introduced into the video channel at the headend. When a customer subscribes to the secured service, a positive trap is installed at the subscriber's residence to remove the jamming signal.

A disadvantage of this mechanism is that customers could obtain the filter through theft or other illegal means. Another disadvantage is the loss of resolution in the protected channel's video caused by the filter.

Negative trapping requires placing a trap at the homes of customers that do not subscribe to the channels to remove the signal from the cable drop. This does not cause any picture degradation because the trap is not in the line of service of customers who subscribe to the protected channel. However, there may be some degradation in the unprotected adjacent channels if the filter traps out more than the protected channel.

### 6.1.2 Addressability

Addressability is the ability to remotely control parameters of the subscriber's reception of signals by transmitting signals addressed to that subscriber's equipment. In general, a digitally encoded special frequency signal is added to the system to provide this control. Addressability offers the capability that allows the system operator to entirely disconnect and reconnect service without truck roll. This can be achieved within the set-top box or with the tap if it is addressable and active. Addressable taps (smart taps) can be used to disconnect or reconnect service, or even descramble the signal. These kinds of taps require operating power, which is usually drawn from cable plant.

With addressability, the operator can deliver services on demand by remotely enabling or disabling the descrambling capability of the set-top or smart tap. This could be used to control access to premium and pay-per-view channels. Addressability also provides the capability to monitor various alarming functions, power, water usage readings, and so on. Test equipment controlled by computers can monitor systems remotely and switch signal routing before failures occur.

### 6.1.3 De-Scrambling

Scrambling is a way of encoding the video and audio information at the headend to exclude the non-subscribing customers. This mechanism requires the customer's terminal equipment to have the ability to decode (un-scramble) the channel.

The descrambler is usually incorporated inside the cable set-top box. It has the ability to descramble multiple TV channels for about the cost of scrambling one channel. There are two major types of descramblers: **Radio Frequency (RF)** and baseband descramblers.

RF descramblers are designed to reconstruct the TV channel directly onto the cable channel. In baseband scrambling systems, the encoding format for the baseband converter/descrambler is a combination of random or pseudo-random synchronization suppression and/or video inversion. In a popular system, the polarity of the transmitted video is randomly inverted such that the bright areas of

the picture become dark and dark areas become bright. A key that indicates which lines have had their polarity inverted is transmitted to the descrambler. The descrambler then uses the key to reconstruct the original video information. Note that the key is scrambled before it is transmitted to the descrambler.

#### 6.1.4 Off-Premises Systems

The motivation for off-premises systems is that the security-sensitive devices are removed from the subscriber's home and placed on the pole or in a pedestal. This makes tampering more difficult. The headend controls the signals at the pole or pedestal rather than at the home. This eliminates the need for scrambling on the cable plant and also the need for descramblers/converters because the signal is already in the descrambled form.

Most off-premises devices are addressable; specific or all channels can be controlled remotely from the headend. There have been several attempts to adapt addressable converters/descramblers for placement on the pole, but these attempts have not been successful because this approach could deliver only one channel at a time to the entire home. This is not suitable for today's typical home setting, which has multiple TVs and VCRs.

Another form of off-premises security mechanism is the use of *interdiction* technology. This approach is very similar to that of positive trap scheme. The pay TV channels are transmitted through the cable plant without any security. The protection is then added on the pole at the subscriber module by adding interference signal(s) to the unauthorized channels. An electronic switch is used to turn the signals off.

#### 6.1.5 OpenCable Security Initiative

**Section 4.2.2** provides an overview of the OpenCable initiative. OpenCable defines two digital interfaces that allow digital TV programming to be transferred externally after the conditional access scrambling has been removed. These are the Point-of-Deployment module (POD) to the host interface and the IEEE-1394 interface. Conditional access is the means by which access to specific services is granted to the user based on payment for those services. The POD module provides all the conditional access capabilities for the host device via the OCI-C2 interface within a single PCMCIA module. The POD receives an encrypted **MPEG-2** video stream and decrypts services for which it is authorized and the clear text MPEG stream is made available. To prevent unauthorized copying (duplication) of the signal, copy protection may be added to services requiring copy restrictions.

The POD module employs an external interface on the digital cable receiver and this interface itself needs to be protected because the device that is hosting the POD may not be a trusted device. Even if the host can be trusted, snooping can be

occurring on the communication path. A patented technique known as the dynamic feedback arrangement scrambling technique (DFAST) can be used to protect the interface. DFAST is used in combination with the Digital Encryption Standard. It relies on unique secret keys and intellectual property to process those keys.

To implement DFAST, a license is needed from CableLabs, who owns the licensing rights to the patented technology. This agreement is called the POD-Host Interface License Agreement (PHILA).

#### 6.1.5.1 Output Control

Outputs from a digital set-top box can be used to produce perfect copies of received signals. The only approved digital output from a digital set-top box is the IEEE-1394 interface when equipped with the Digital Transmission Content Protection (DTCP) system (also known as the “5C” system). The name “5C” refers to the name of the five companies that jointly defined the specifications for content protection: Hitachi, Intel, Panasonic, Sony, and Toshiba. When a product provides this interface, the manufacturer is required to sign a license agreement with the Digital Transmission Licensing Administrator (DTLA) to use the technology.

Analog copy protection has been in effect for many years now through the use of Macrovision technology. The Macrovision system adds a series of electronic pulses to the vertical blanking interval (VBI), and it contains extra sync pulses and falsifies video data. So, a Macrovision-encoded video signal displays normally on the TV set.

A VCR on the other hand tries to make a faithful recording of its input and in accomplishing that task, it tries to record the signal containing the extra sync pulses. The automatic gain control (AGC) sees the extra sync pulses and the fake video data and it sets its level incorrectly. The real video information in the frame gets recorded at a much lower level than it normally would, which plays a non-descript image during the TV playback. PHILA rules require that the licensed device include the Macrovision technology on all applicable analog interfaces.

## 6.2 Data/Voice Services Security

In contrast to physical threats, network security issues are not bounded by the location of the equipment. From this perspective, network security issues are much more threatening than physical issues. The source of network threats can share the same network as the target, or it can be thousands of miles away and with no direct connection to the target. This makes tracking sources of intruders very difficult; therefore, it is paramount that the customers are protected from harm from outside of the network. Typical network security issues include:

- Unauthorized access (see [Section 6.2.1](#)) - commonly known as hacking.
- Virus attacks (see [Section 6.2.2](#)) - distribution of materials that are harmful to the local or its related equipment.
- Signal Interception (see [Section 6.2.3](#)) - Interception of the signal in the process of transmission.
- Service Fraud (see [Section 6.2.4](#)) - Unlawful access to services/applications provided.

### 6.2.1 Unauthorized Access

Among these, unauthorized access (hacking) is probably the dominant type of security threat due to its variations and wide-spread implications. For example, a hacker with access to the network server would have access to customer information, leading to such as disclosure or modification of the information. Or a hacker with access to the network management systems would be able to change the **Quality of Service (QoS)** parameters of the customers, resulting denial of service and possibly **Service Level Agreement (SLA)** disputes. Networks can be protected from unauthorized access using authorization or authentication mechanisms.

### 6.2.2 Virus Attacks

With the ubiquitous Internet, virus attacks have become a serious security threat as applications such as electronic mails and other messaging services accelerate the distribution of the virus. The effect of a virus attack ranges from wiping out local data to automatic forwarding to propagate to the server, which could eventually cause the system to shut down. Typical protection against virus attacks is using higher-layer virus scanning applications.

### 6.2.3 Signal Interception

Examples of signal interception include eavesdropping on the voice network, where circuits are tapped to listen to private conversations, or “hi-jacking” data in the packet network, where information is intercepted during the routing process. As the use of electronic commerce gains acceptance, signal interception can result in great monetary loss when financial information such as credit card information is intercepted during electronic transaction. To protect user privacy, data encryption techniques are normally applied to avoid information misuse.

### 6.2.4 Service Fraud

Two major sources of service fraud are subscription fraud and masquerade fraud. Masquerade occurs when a wrongdoer pretends to be a bona fide subscriber, while subscription fraud involves legitimate users accessing services that they are not entitled to.

Broadcast networks or services are particularly vulnerable to service fraud because services are easily accessible. A common example of subscription fraud is the unlawful access to restricted premium channels on the cable TV network. Network operators protect its services and customers from such threats by encoding signals transmitted, thus making the signal useless without the appropriate decoding tool.

### 6.2.5 DOCSIS Security Initiative

A **Data Over Cable Service Interface Specification (DOCSIS)**<sup>TM</sup>-based cable modem is used to provide high-speed access to services such as Internet access, **Internet Protocol (IP)** telephony, video conferencing, telecommuting, etc.

The security of data transport services and **Customer Premises Equipment (CPE)** devices that use cable modems to connect to public data networks are needed to protect against threats from malicious attacks. A DOCSIS-based cable network provides traffic filtering like in dedicated subscriber line systems, which reduces the risk of attacks that may target CPEs.

The following subsections look at the security features defined in DOCSIS as related to data transport and CPE systems.

#### 6.2.5.1 Data Transport Services Security

The baseline data-over-cable security specification provides for privacy of the DOCSIS modem user’s data across the cable network. This is accomplished by encrypting traffic flows between the **Cable Modem (CM)** and the **Cable Modem Termination System (CMTS)** located in the cable **headend**.

The CMTS enforces the encryption of traffic flows with the use of an authenticated client/server key management protocol, in which the CMTS (server) controls the distribution of keys to the CMs (clients).

The DOCSIS data transport security has two protocol components: an encapsulation protocol and a key management protocol. The key management protocol provides a means for a secure distribution of keys from the CMTS to the CMs. The encapsulation protocol is used to encrypt packets across the cable network and it defines the frame format for carrying encrypted packets within the DOCSIS frames. It also defines a set of supported data encryption and authentication algorithms and rules for applying the cryptographic algorithms to a DOCSIS MAC frame's data.

**Table 6-1** shows different kinds of possible threats, examples of these threats, and remedies for them.

**Table 6-1** Attacks and Remedies for Data, Voice, and Video Information

Threats	Examples	Prevented by
<b>Data</b>		
Data Privacy	Eavesdropping and intercepting sensitive data	Encryption
Service Fraud	Masquerading as another user	Modem and headend authentication
System Intrusion (server or other customers)	Unauthorized access or modification to proprietary information	Headend authentication, personal firewall
<b>Voice</b>		
Privacy	Eavesdropping	Encryption
Service Fraud	Long distance calls using false or stolen account	Modem authentication
<b>Video</b>		
Service Fraud	Accessing unauthorized channels, masquerading as another users	Encryption, modem authentication
<b>Control</b>		
Intrusion at Headend	Collecting shared secret keys for all modems	Modem authentication, careful security design
Intrusion at Modem	Malicious reconfiguring of modem	Headend and download authentication

### 6.2.5.2 CPE System Security

A DOCSIS-based cable network access system provides traffic filtering similar to remote access servers used in dedicated-line network service providers. These kinds of systems are prone to unauthorized access to system files using TCP/IP NetBIOS (NBT) and System Message Block (SMB) file-sharing protocols that run on various Microsoft Windows variants (e.g., Windows for Workgroups, Windows 95, Windows 98, Windows NT).

If the IP address of a system is known, a series of attacks can be initiated to gain unauthorized access. Windows PCs employ the TCP/IP NetBIOS (NBT) name service for advertising and for determining names and addresses of shared system resources on a **Local Area Network (LAN)**.

If a PC attached to a LAN has file and print sharing enabled, it will advertise its services across the cable-based LAN interface, and any other devices on the same cable-based LAN can determine the name and address of the PC offering the shared file and print services. Once the name and address of a Windows-shared service is known, a point-to-point NBT session can be established with the shared service. The cable service provider can address this problem by informing the customers and requiring them to disable file and print sharing.

### 6.2.6 Authorization, Authentication, and Encryption

Authentication is the process of determining whether a user is who he/she claims to be. In a network, authentication is enforced by prompting the user for a login name and password.

Authorization usually proceeds authentication. Whereas authentication “identifies” the user, authorization determines the permission that the authenticated user is entitled to. For example, it determines what privileges of use that the user has in terms of file/directory access, the duration of the access, available storage resources in the server, etc. Authentication and authorization together restrict the access into the network, and enforces usage privileges of permitted users. The two processes are often integrated and various levels of complexity (and thus effective security) are available.

While authentication and authorization protect the network from hackers, they do not protect signals being intercepted during the transmission, and neither does encryption. Nonetheless, encryption does protect users from signal interception by making the information useless without a specific decrypting “key” known to the intruder. Encryption is essentially substitution and scrambling of original information using a “key” known to both the server and the intended signal recipient. Common encryption standards include the **Data Encryption Standard (DES)** and the newer **Advanced Encryption Standard (AES)**. Various levels of encryption complexity are possible depending on the implementation. Note that encryption is also used to protect digital video content from unauthorized access.



### 6.2.7 Other Higher-Layer and/or Integrated Solutions

Authentication, authorization, and encryption are the building blocks of many higher layer or integrated solutions available in the market today. Most network management systems have built-in mechanisms that monitor and protect the network and its users through a combination of authentication, authorization, and encryption processes. However, such measures provide very limited protection. For instance, the currently popular network management protocol, the **Simple Network Management Protocol (SNMP)**, uses default or null passwords within the interaction between the manager and the various elements, which provides network operators with a false sense of security.

For services involving the public Internet, the use of a firewall has almost grown into a standard in recent years. A firewall is a set of programs located at a network gateway server, and it protects resources within the network by examining each network packet to determine whether to forward or discard it. The decision is made based on the domain name or IP address of the packet. Other features in a firewall include event logging, reporting, and automatic alarms.



## 7 Evolution of HFC Networks

### 7.1 Technology and Market Trends

The marketplace has been transformed with the passage of the Telecommunication Act of 1996 (TA96) and with the rapid rise of Internet usage and new services. TA96 opened up markets to competition that is finally being realized. **Competitive Local Exchange Carriers (CLECs)** are offering **Digital Subscriber Line (DSL)** services using leased and shared facilities. Cable multiple service operators (MSOs) are branching out from their cable TV base to offer high-speed data via cable modems and are beginning to offer voice services as well.

Opportunities abound to offer new services to residential/business customers on their existing cable infrastructure to generate additional revenues and strengthen customer loyalty. The use of a cable network infrastructure enables high-speed access to data services, which opens doors for cable operators to offer value-added **Internet Protocol (IP)**-based services to a high number of residential and small business customers. These services include, in addition to the existing on-demand services

- Always-on, high-speed Internet access
- Online shopping and banking
- **Virtual Private Network (VPN)**
- Telecommuting
- Enhanced online gaming
- Personal video conferencing
- IP telephony
- Interactive services.

With the new opportunity for these value-added services, there is a need to engineer a network that is highly scalable, reliable, and optimized to deliver “lifeline” telephony and **Quality of Service (QoS)** guarantees required by these services to many subscribers simultaneously.

According to Cable Datacom News, broadband coaxial cable passes by more than 110 million homes in North America and more than 75 million are cable TV subscribers. The Cable Datacom News publisher Kinetic Strategies Inc., estimated that the North American service providers counted about 9.3 million residential broadband Internet subscribers as of June 1, 2001. This is approximately equal to a 8.2-percent household penetration, of which 6.4 million are **Cable Modem (CM)** customers and 2.9 million are DSL customers.

Kinetic Strategies also estimates that MSOs added nearly 1 million broadband Internet customers in the first quarter of 2001, which is 76 percent more than the 560,148 added by DSL providers.

**Table 7-1** profiles the residential broadband Internet market in North America.

According to a recent study by IDC, a market research firm, the global CM access grew by about 178 percent to 7.2 million customers in 2000 and CM equipment revenue grew by 122 percent in the same year.

In the United States, whose market represents 53 percent of the global CM market, CM services subscriptions such as Excite@home and Road Runner grew by 171 percent to 3.8 million customers.

**Table 7-1** Residential Broadband Internet Market in North America

	DSL	Cable	Total
Subscribers as of 6/1/01	2,913,636	6,450,916	9,364,552
Subscribers as of 3/31/01	2,543,938	5,800,103	8,344,041
Q1-01 Subscriber Additions	560,148	986,081	1,546,229
Q1-01 Average Adds/Week	43,088	75,852	118,941

Source: Kinetic Strategies Inc.

## 7.2 The Road Ahead for HFC

The road ahead for cable operators looks very promising and as these operators look forward to competing head-to-head with telecommunications companies for data and voice customers, network reliability is a main concern. To stay ahead of the competition, cable operators need to engineer their network to overcome the challenges they face today.

The first challenge that needs to be met is increased network reliability and the ability to support lifeline telephony services. CM systems rely on a shared network infrastructure similar to that of an office **Local Area Network (LAN)**. Hence, the available bandwidth is shared among several users during their sessions and there are genuine concerns that users will experience poor performance as the number of users increase on the network.

With **Data Over Cable Service Interface Specification (DOCSIS)<sup>TM</sup> 1.1**, network operators are now able to offer multiple level of services on a shared cable infrastructure and provide guaranteed QoS levels to each service and user. DOCSIS 1.1 (see **Section 4**) defines enhancements to the MAC protocol of the earlier release DOCSIS 1.0, which allows cable operators to isolate multiple data streams from each cable modem and apply different QoS treatment to these streams. This translates into increased revenue due to the ability to provide a customer **Service Level Agreement (SLA)** and offer highly profitable tiered voice and data services, and other QoS-based services at lower operating costs.

To support the reliable delivery of quality high-speed data and telephony services, there is also a need for an integrated **Cable Modem Termination System (CMTS)**/cable access system that would reliably support the cable operator's needs for today and tomorrow. This increases reliability, and reduces management and administration complexity with support for IP-based voice, data, and video services with a common platform. This means reduced space and power requirements, lower installed first cost, and lower lifecycle cost.

The HFC network must be scalable to support low penetration and low penetration markets with a single platform, and greatly simplified network management and administration. A simple network management and administration will enable true scalability, more efficient use of scarce network resources, increased reliability, and maximized benefit of DOCSIS-based networks. Also the network should be able to provide increased security and network privacy.

Interoperability is a big issue in the cable industry, and there have been standards initiatives working to ensure interoperability among cable vendor equipment. OpenCable, DOCSIS, and PacketCable are major initiatives in this arena. Interoperability and open system interfaces is the key to leveraging the opportunities presented by the HFC network.

The following is an excerpt from the Kinetic strategies report for the DOCSIS Infrastructure Deployment Forecast:

*The North American Market for Standards-Based Cable Modem Products and Services 2000-2004 estimates there will be more than 20 million installed cable modem customers in North America by year-end 2004, up from 4.8 million at the end of 2000. Sales of DOCSIS cable modems, cable modem termination system (CMTS) and IP switching equipment are projected to exceed \$6 billion through 2004. Cable modem service revenue is projected to exceed \$20 billion.*

Open access to the HFC infrastructure has been an obstacle to maximizing the new revenue benefits.<sup>1</sup> There have been technology obstacles that imposed legitimate barriers to open access implementations. A barrier to open access was the proprietary implementation of CMTS and first-generation DOCSIS equipment. With open access, operators provide the access to third-party providers, who can then offer value-added services on the same HFC infrastructure. This gives subscribers the ability to select services from multiple providers on either a subscription or pay-per-use basis. Also, open access enables the subscriber to select from multiple providers based on the competitiveness of their offerings, e.g., Internet access from a selection of ISPs, video service from the MSO, and voice from CLECs or an **Interexchange Carrier (IXC)**.

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1. Open access refers to the ability for multiple providers to deliver services, content, or applications via a shared HFC access network.

The OpenNet coalition, an **Internet Service Provider (ISP)** lobbying group, began the quest to open United States CM networks to multiple ISPs in early 1999. Initially, there was little progress, but recently there have been some breakthroughs.

To finalize their merger in January 2001, America Online Inc., and Time Warner agreed to cable open access regulations mandated by both the Federal Communications Commission (FCC) and Federal Trade Commission (FTC) in December 2000. The FTC mandated AOL Time Warner (AOLTW) to offer at least one independent ISP service on each Time Warner Cable system before AOL itself begin offering service. Then Time Warner Cable must also provide at least two other non-affiliated ISPs within 90 days of AOL's launch. To strengthen the FTC's open access requirements, the FCC mandated the following:

- AOLTW cannot unfairly favor its Internet offerings when an existing or potential customer request for ISP information.
- AOLTW must allow each ISP to control the content on its subscribers' first screen and may not require an ISP to include any content as a condition of obtaining access to AOLTW cable systems
- AOLTW cannot force cable modem customers to go through an affiliated ISP, such as AOL or Road Runner, to reach the ISP of their choice
- AOLTW must permit each ISP to have a direct billing arrangement with the cable modem customers they serve
- AOLTW may not create contracts that prevent ISPs from disclosing terms of their agreement to the FCC.

Finally, a key factor to maximizing revenue is the ability of the cable operators to quickly and cost-effectively provision new services and add new subscribers. This concept of "true customer self-care" involves plug and play activation of cable modems and the ability for subscribers to make changes or subscribe to new data and voice services without the need for any human interaction. This has the advantage of lowering provisioning and administration costs by eliminating the need for field personnel to visit every subscriber's home. Also, annual ongoing network operations costs could be reduced by as much as \$50 per subscriber.

## Appendix A: Alternatives to Cable Network for Broadband Access

The focus of this document has been on the capability and potential of cable networks. Currently, the cable network has a large share of the access market that delivers solution packages offering voice, video, data, and high-speed-Internet access services. However, despite its dominance, the market is crowded with other competing technologies.

An “up-and-coming” technology that allows a **Local Exchange Carrier (LEC)** to leverage its legacy infrastructure is the **Digital Subscriber Line (DSL)**, which has been gaining market shares from the cable network.

Other overlaying alternatives have also been deployed in recent years such as the **Broadband Fixed Wireless Access (BFWA)**, and the **Fiber-In-The-Loop (FITL)** networks. While cable and DSL networks provide cost-effective immediate solutions to the access demand, BFWA and FITL systems offer high-capacity “futuristic” alternatives.

This Appendix provides a brief overview of these technologies. **Section A.1** discusses DSL, **Section A.2** looks at wireless access, and **Section A.3** covers fiber.

### A.1 The xDSL Family of Access Technologies

DSL provide a means of transmitting data at high speeds over existing copper access lines in the **Local Loop**. That is, it uses the same copper loops that are in place today to deliver telephony services, and enables the delivery of higher speed data.

To do this, a pair of “modems”<sup>1</sup> are placed at either end of an existing copper loop. One of the “modems” is at the customer location where it connects to the customer’s computer or a local network. The other “modem” is on the network end of the copper loop, typically in the **Central Office (CO)**. These two modems perform the processes needed to transmit broadband data over the copper line. The network side modems are typically aggregated in a device known as a **Digital Subscriber Line Access Multiplexer (DSLAM)**.

A DSLAM is typically a modular device located in a CO that takes line cards and can support up to hundreds or thousands of DSL ports. The line cards typically differ depending on the type of DSL technology they can support. The DSLAM terminates

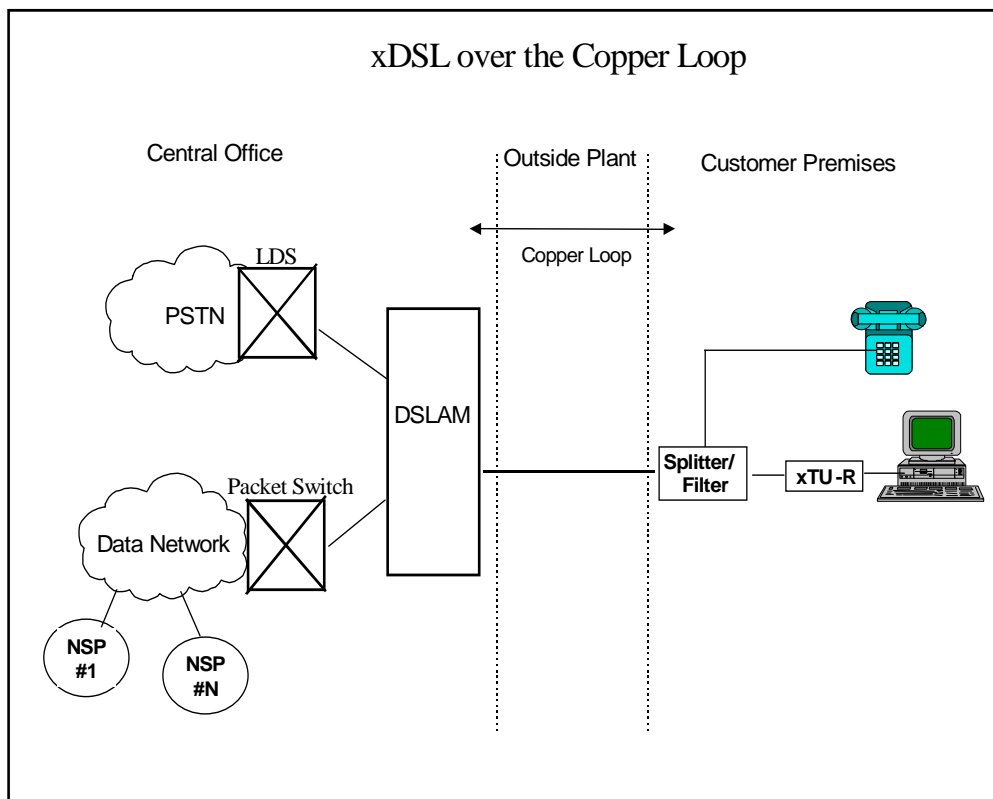
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1. In actuality, the equipment placed on each end of the line are not typically referred to as modems, but rather as transceiver units. The network side is the xDSL Transceiver Unit – CO (xTU-C). Likewise, the DSL unit at the customer’s premises is referred to as a xDSL Transceiver Unit – Remote (xTU-R). They serve a function that is analogous to dial-up modems in the **Public Switched Telephone Network (PSTN)** and together, they enable broadband data to be sent over the copper line.

the individual DSL lines and multiplexes the data on a single physical high-speed interface toward the **Core Network**.

Depending on the type of DSL, **Plain Old Telephone Service (POTS)** may be simultaneously supported on the same copper loop as DSL. In this case, the DSLAM also contains a POTS splitter, which combines the broadband data and POTS signals onto the same line. At the customer's premises, a splitter is used to separate the two signals, connecting the POTS service to the existing inside telephone wiring, and connecting the data service to the DSL "modem" and ultimately the customer's personal computer.

**Figure A-1** shows a high-level view of a generic DSL system supporting both POTS and data. In this figure, copper connects the subscriber to his or her local CO. At the CO, a DSLAM connects to the PSTN via the circuit switch or Local Digital Switch (LDS) for POTS and a data network via the Packet Switch for high-speed data service.



**Figure A-1** High-Level View of a Typical xDSL Architecture

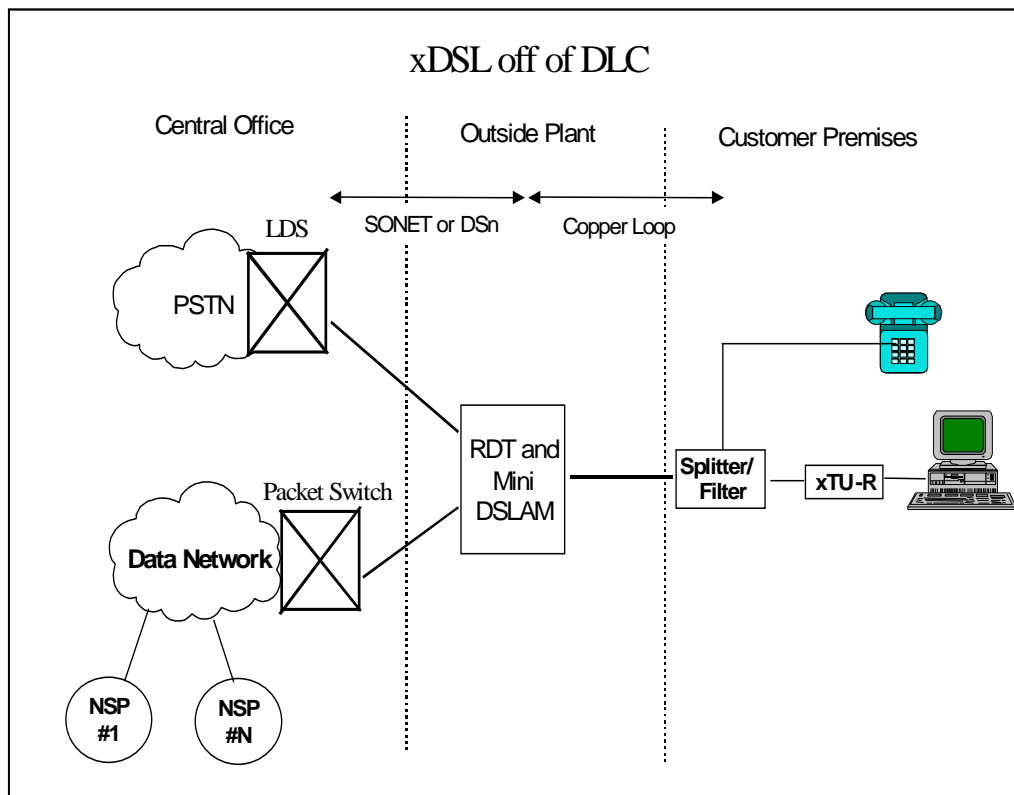


Many of today's telephony subscribers are served by a **Digital Loop Carrier (DLC)**. DLC has been deployed for many years as a way to lower the infrastructure costs for telephony.

In a traditional, non-DLC telephony network, a copper pair for each and every subscriber is run from the CO to the customers' premises. This leads to tens of thousands of copper pairs originating in a CO. DLC provides a way of gaining additional multiplexing coming out of the CO.

With DLC, DSIs are taken from the CO to a **Remote Digital Terminal (RDT)** located in the outside plant. Individual copper pairs are used from the RDT to each subscriber. This architecture has significant implications for DSL. As was discussed earlier, DSL is enabled by placing a pair of "modems" on either end of the copper loop. With DLC, the copper loop terminates in the outside plant, rather than in the CO. Therefore, the CO "modem" needs to also be placed in the outside plant.

When a DLC system is deployed, the xTU-C/DSLAM is located with the RDT. This is accomplished by either collocating a mini-DSLAM with the RDT or placing the DSLAM very near to the RDT. **Figure A-2** gives a high-level view of this type of architecture with a DLC.



**Figure A-2** High-Level View of the xDSL Architecture with a Digital Loop Carrier (DLC)

The xDSL family shares some overall advantages and disadvantages. On a positive note, xDSL has several overall advantages. To reduce infrastructure costs, xDSL utilizes the embedded copper bandwidth. xDSL is simply a modem pair. To activate service, equipment usually only needs to be placed in the CO and at the customer premises to activate xDSL service. It has a reasonable bandwidth and data rates to support a wide range of services. Unlike dial-up modems, it provides constant performance in the access network. **Asymmetric Digital Subscriber Line (ADSL)** and **High-bitrate Digital Subscriber Line (HDSL)** have experienced a fair share of deployment, so xDSL technology can be considered mature and be deployed where copper loops qualify for DSL service.

However, xDSL is not ideal for every situation. All forms of xDSL are distance limited. The available data rates over DSL lines decrease with distance. Another problem is that not all copper loops can support DSL service. The use of load coils, bridge taps, degraded lines, or unshielded wiring can disqualify service or cause problems in the quality of DSL service. For some types of DSL, such as **Very High-bitrate Digital Subscriber Line (VDSL)**, the lack of equipment interoperability can also pose problems.

For more information on the different flavors of xDSL, see SR-NOTES-SERIES-05, *Telcordia Notes on DSL*. Ordering information for that Telcordia document is in **Appendix C**.

## A.2 Wireless Access Technologies

Another high-speed access technology for consideration in the local loop is **Broadband Fixed Wireless Access (BFWA)** or **Wireless Local Loop (WLL)** technology. There are two primary technologies under BFWA: **Local Multipoint Distribution Service (LMDS)** and **Multipoint Multichannel Distribution Service (MMDS)**.

MMDS, also known as wireless cable, has been in operation for several years to distribute video signals. It operates between 2.150 GHz and 2.682 GHz in the United States. Traditionally, MMDS systems provided for 33 analog video channels. But by migrating to digital technology, MMDS could provide over 150 digital channels in addition to broadband data. Just like wired cable, a 6-MHz television channel can support 27 Mbps of throughput downstream.

In general, there is a single **headend** facility adjacent to a single broadcast antenna that distributes the services to subscribers. A subscriber will need an antenna to pick up the video signal, a set-top box to convert the MMDS signal to a format acceptable for their television, and/or an interface for a PC. A single MMDS broadcast antenna can cover an area with a 35-mile radius.

MMDS is a two-way technology and can transmit downstream signals and receive upstream signals. However, it is highly asymmetric, with much more bandwidth available for downstream than for upstream.

LMDS is another fixed wireless system that employs transmitters in 3-mile radius cells to cover their serving area. In general, there is a single headend facility that gathers the video, telephony, and data signals for distribution to the LMDS cell antennas, which broadcast the signal to subscribers. Distribution to the cells from the central hub can be by fiber or backhauled via radio. The cells then broadcast the signal to subscribers. A subscriber will need a small antenna (~0.5 m in diameter) to pick up the signal. A set-top box will be required to convert video signals to a format acceptable for the television. The subscriber antenna must be within line of sight of the transmitting antenna to receive the signal. Any foliage or buildings between the transmitting and receiving antennas will block the signal.

LMDS operates around 26 or 28 GHz and in the United States there is about 1300 MHz of spectrum available for LMDS. With this, LMDS systems can provide a maximum capacity close to that of OC-3 (155 Mbps).

A primary advantage of FWA systems such as LMDS and MMDS is the ease of deployment and installation. As wireless technologies, they offer faster time-to-market by eliminating the physical connection between the service provider and subscribers, which also leads to low startup and infrastructure investment. Through an advanced radio-frequency design tool, LMDS and MMDS networks can be designed with optimized coverage and offer service level guarantees comparable to traditional telephony services.

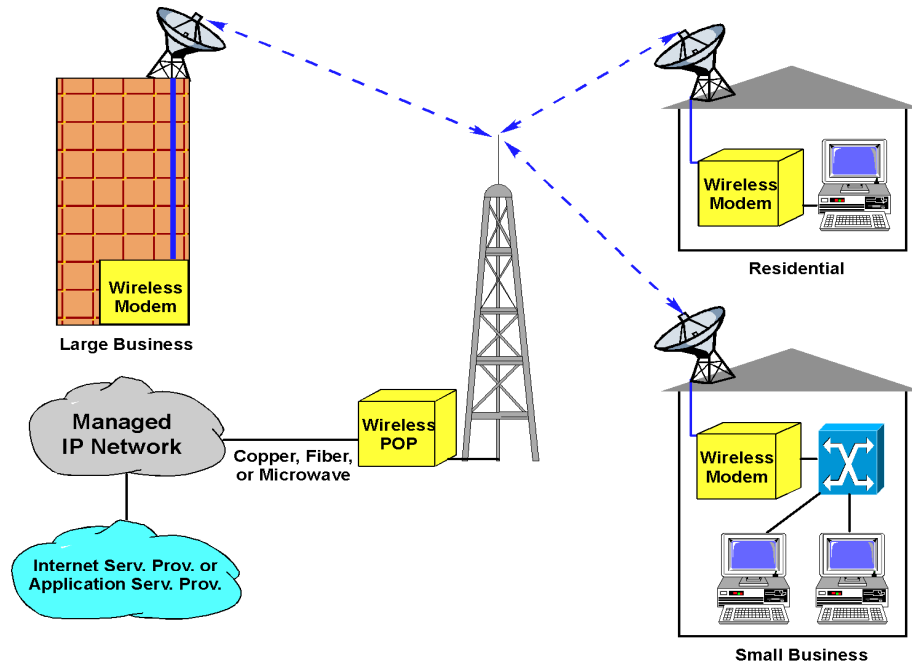
More importantly, LMDS/MMDS offers large amounts of bandwidth, providing the ability to handle high-volume data traffic, the capacity for interactive two-way service, and the flexibility to allow combinations of services such as Internet access, **Voice over Internet Protocol (VoIP)**, Private Virtual Network (PVN), IP based videoconferencing, etc.

However, with any wireless system, achieving ubiquitous coverage is a challenge. Shadowing from buildings or mountains within the city and interference from some satellite services may limit service availability. This is more severe for LMDS where the receiving antenna must be within line of sight of the broadcasting antenna.

Furthermore, LMDS is limited by rain attenuation and can be affected by foliage. These factors limit the availability and quality of LMDS services, and cause small cell sizes to be used to maintain high service availability. A fixed wireless network also requires a very detailed and precise network design, which can potentially ramp up deployment capital. As with all wireless networks, signals are broadcast throughout the coverage area. This also raises security concerns such as signal interception and unauthorized access.

**Figure A-3** illustrates a generic BFWA network based on an **Internet Protocol (IP)** backbone. The diagram shows large businesses, small businesses, and residential customers accessing the Internet using the BFWA system. Each subscriber is connected to the wireless access network through a modem, which is in turn connected to a rooftop transceiver. Transceivers communicate with a base station via the radio link. Base stations are located at, or near the wireless Point of Presence (POP), which aggregates and manages traffic going into the core network. The connection between the POP and the core network can be copper, fiber, or wireless.

In this illustration, the core network is an IP network that is connected to the public Internet (not shown) via an Internet Service Provider (ISP) or the equivalent.



**Figure A-3** Generic BFWA Network Based on an Internet Protocol (IP) Backbone

For more information on the BFWA network, see SR-NOTES-SERIES-06, *Telcordia Notes on Fixed Wireless*. Ordering information for that Telcordia document is in [Appendix C](#).

### A.3 Fiber-Based Access Technologies

Another alternative to cable network is to deploy new, FTTL access networks, such as **Fiber-To-The-Curb (FTTC)**, **Fiber-To-The-Building (FTTB)**, or **Fiber-To-The-Home (FTTH)**. These are generally referred to as FTTx. In all of these fiber-based systems, there is a Host Digital Termination (HDT), or Optical Line Termination in the network (i.e., in the CO). Fiber connects the HDT to an **Optical Network Unit (ONU)** that lies close to the customer. The ONU converts the optical signals to electrical signals.

The primary difference between the different types of fiber-based networks is the location of the ONU. **Figure A-4** and **Figure A-5** illustrate the high-level network structures for FTTC and FTTH, respectively. In FTTC, the ONU is located “at the curb” and a single ONU will serve between 8 and 32 subscribers. Subscribers are connected to the ONU with a combination of copper and coax. FTTB brings fiber all the way to the entrance of a building. The building is typically either a commercial business or a multi-dwelling unit. FTTH is the analogous for the

residential market, with fiber running all the way to the subscriber's house. The ONU is in these cases would be located on the customer's premises.

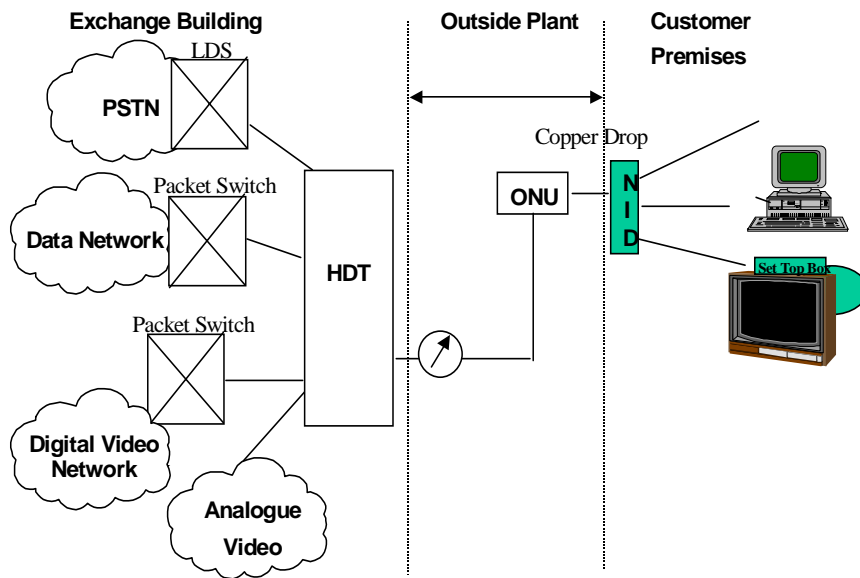


Figure A-4 High-Level View of a Fiber To The Curb (FTTC) Network

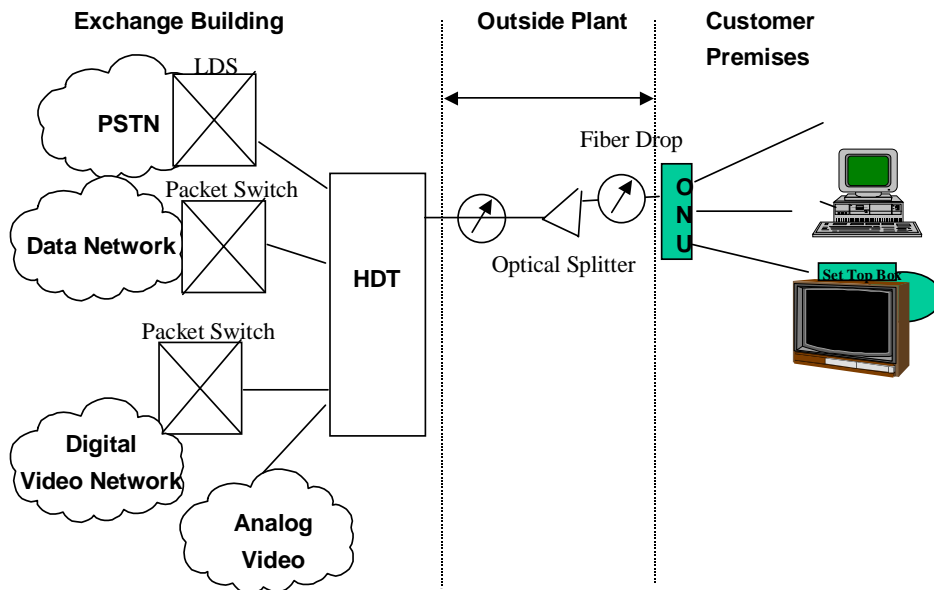


Figure A-5 High-Level View of a Fiber To The Home (FTTH) Network

Some other variations between FTTC, FTTB, and FTTH architectures due to differences from either technology and/or vendor design or implementation choice include:

- The number of fibers each ONU uses
- The method employed to power ONUs
- The method used to combine various signals for transport between the HDT and ONUs

There are a number of advantages associated with fiber-based access systems.

The bandwidth capabilities of these systems are only limited by the electronics located at the HDT and ONUs and the technology is constantly increasing this capability. This implies that the fiber plant is truly “permanent” in the sense that future upgrades to increase bandwidth can be accomplished at the HDT and ONUs without disturbing the plant in between. Also, by placing intelligent network elements near to the customer, remote provisioning, maintenance, and testing are enabled.

By eliminating much of the metallic connection between the exchange and the end customer, these systems effectively reduce exposure to electrical interference and noise. Additionally, the use of digital signal processing techniques means that the services carried are not subject to the analog signal degradations found in the current analog network.

However, because these architectures bring fiber and ONUs relatively close to the end customer, much or all of the current copper network is bypassed. This results in little leverage from this embedded network and, therefore, higher initial construction costs for FTTx. Additionally, as this approach distributes some of the functionality performed at the switch in a copper architecture out to the ONUs where the number of customers sharing this functionality at each ONU is much less, the costs for electronics tend to be higher. All these factors lead to FTTx being expensive to deploy.

Also, some scheme must be used to provide distributed powering as the ONUs are distributed widely throughout a secondary network that require power to operate. The fiber cables cannot carry enough power for this; therefore, power must be either carried to the ONUs by a metallic network (either copper or coax) or accessed locally at each ONU site. The distributed nature of this network also impacts the provisioning of back-up power capabilities.

Although fiber networks are typically considered very reliable, the distributed electronics of the FTTC approach must also be very reliable to afford overall network reliability. The intelligence of these network elements and the capability for remote alarms and diagnostics should help alleviate these concerns.

For more information on various FITL architectural options, see SR-NOTES-SERIES-07, *Telcordia Notes on FITL*. Ordering information for that Telcordia document is in Appendix C.





## Appendix B: Major Players in the Cable Industry

**Section B.1** through **Section B.5** list equipment makers in various segments in the cable market. For your convenience, the web site for each company has also been listed.

This list should not be considered exhaustive, and Telcordia is not recommending products/services of these particular companies be purchased.<sup>1</sup>

### B.1 DOCSIS Cable Modem Vendors

- 3Com (<http://www.3Com.com/cablenow>)
- Alcatel SA (<http://www.alcatel.com>)
- Ambit Microsystems (<http://www.ambit.com.tw>)
- Arris (<http://www.arris-i.com>)
- Askey(<http://www.askey.com/>)
- Asustec (<http://www.asus.com.tw>)
- BestData (<http://www.bestdata.com>)
- CIS Technology (<http://www.cis.com.tw>)
- CastleNet (<http://www.castlenet.com.tw>)
- Cisco Systems (<http://www.cisco.com/cable>)
- Com21 ([www.com21.com](http://www.com21.com))
- Coresma (<http://www.coresma.com>)
- D-Link (<http://www.coresma.com>)
- DX Antenna (<http://www.dx-trading.com>)
- Daewoo (<http://www.daewoo.com>)
- Dakos (<http://www.dakos.co.kr>)
- E-tech ([www.e-tech.com](http://www.e-tech.com))

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- Elsa ([www.elsa.com](http://www.elsa.com))
- Ericsson (<http://www.ericsson.com/cablemodems>)
- GVC (<http://www.gvc.com>)
- Global Telemann (<http://www.telemann.com>)
- HighSpeed Surfing (<http://www.highspeedsurfing.com>)
- Iicable (<http://www.icablesystem.com>)
- JooHong (<http://www.jooHong.co.kr>)
- Maspro Denkor (<http://www.maspro.co.jp>)
- Matsushita - Panasonic(<http://www.panasonic.com>)
- Motorola (<http://www.gi.com>)
- NEC (<http://www.nec.com>)
- NetGear (<http://www.netgearinc.com>)
- Nortel (<http://www.nortelnetworks.com>)
- Ole Communications (<http://www.olecomm.com>)
- PowerCom(<http://www.powercom.com.tw>)
- SOHOWare (<http://www.sohoware.com>)
- Saejin (<http://www.sjtm.co.kr>)
- Samsung (<http://www.samsungtelecom.com>)
- Scientific Atlanta (<http://www.scientific-atlanta.com>)
- Sharp (<http://www.sharpusa.com>)
- Teldat (<http://www.teldat.es>)
- Tellabs (<http://www.tellabs.com>)
- Terayon(<http://www.terayon.com/>)
- Thompson(<http://www.thomson-broadband.com>)
- Toshiba(<http://www.toshiba.com/taisnpsd>)
- TurboComm(<http://www.turbocomm.com.tw>)
- TurboNet (<http://www.turbonet-comm.com>)
- U.S. Robotics (<http://www.usrobotics.com>)
- Xrosstech (<http://www.xrosstech.com>)
- Zoom Telephonics(<http://www.zoom.com/cable>)
- ZyXel (<http://www.zyxel.com>)

## B.2 DOCSIS Cable Modem Termination System (CMTS) Vendors

- 3Com (<http://www.3Com.com/cablenow>)
- ADC - Broadband Access Systems (<http://www.basystem.com>)
- Arris (<http://www.arris-i.com>)
- Cadant (<http://www.cadant.com>)
- Carrier9 (<http://www.carrier9.com>)
- Cisco Systems (<http://www.cisco.com/cable>)
- Coresma (<http://www.coresma.com>)
- Motorola (<http://www.gi.com>)
- Pacific Broadband Communications (<http://www.pbc.com>)
- RiverDelta Networks (<http://www.riverdelta.com>)
- Riverstone networks (<http://www.cabletron.com>)
- Tellabs (<http://www.tellabs.com>)
- Terayon(<http://www.terayon.com/>)

## B.3 Cable Internet Service Provides and Systems Integrators

- @Home Network (<http://www.home.net>)
- Befera Interactive Cablenet (<http://www.the-bridge.net>)
- Convergence.com (<http://www.convergence.com>)
- Earthlink (<http://www.earthlink.net>)
- High Speed Access Corporation (<http://www.hsacorp.net>)
- RCN (<http://www.rcn.com>)
- Road Runner ([www.rr.com](http://www.rr.com))

## B.4 Digital Set-top Converter Box Vendors

- Mitsubishi (<http://www.mitsubishi.com>)
- Motorola (<http://www.motorola.com>)
- Nokia (<http://www.nokia.com>)
- Panasonic (<http://www.panasonic.com>)
- Pioneer (<http://www.pioneercatv.com>)

- RCA (<http://www.rca.com>)
- ReplayTV (<http://www.replaytv.com>)
- Scientific Atlanta (<http://www.sciatl.com>)
- Sony (<http://www.sony.com>)
- TiVo (<http://www.tivo.com>)
- Toshiba (<http://www.toshiba.com>)
- Zenith Electronics (<http://www.zenith.com>)

## B.5 Headend and Distribution Equipment Vendors

- Acterna (<http://www.acterna.com>)
- ADC (<http://www.adc.com>)
- Agilent Technologies (<http://www.agilent.com>)
- Alcatel (<http://www.usa.alcatel.com>)
- Allen Tel (<http://www.allentel.com>)
- Alpha Technologies (<http://www.alpha-us.com>)
- Arcom Labs (<http://www.arcomlabs.com>)
- Belden Wire and Cable (<http://www.belden-wire.com>)
- Blonder Tongue Electronics (<http://www.blondertongue.com>)
- C-Cor Electronics (<http://www.c-cor.com>)
- CableServ (<http://www.cableserv.com>)
- Cadco (<http://www.cadcosystems.com>)
- Channell (<http://www.channellcomm.com/>)
- Commscope (<http://www.commscope.com>)
- Communications and Energy Corporation (<http://www.cefilter.com>)
- Corning (<http://www.corningcablesystems.com>)
- Electroline (<http://www.electrolinequip.com>)
- General Instrument (<http://www.gi.com>)
- Gilbert Engineering (<http://www.gilbertconnectors.com>)
- Holland Electronics (<http://www.hollandelectronics.com>)
- Imedia (<http://www.imedia.com>)
- Lindsay Electronics (<http://www.lindsayelec.com>)

- (<http://www.imedia.com>)
- Microwave Filter Co. (<http://www.microwavefilter.com>)
- Philips Broadband Network (<http://www.digitalnetworks.philips.com>)
- PPC (<http://www.ppc-online.com>)
- Scientific Atlanta (<http://www.sciatl.com>)
- Tektronix Video Telecommunications (<http://www.videotele.com>)
- Times Fiber (<http://www.timesfiber.com>)
- Trilogy (<http://www.trilogycoax.com>)
- Videasonics (<http://www.videasonics.com/>)
- Wegener Communications (<http://www.wegener.com>)



## Appendix C: Bibliography and References

This section includes suggested further reading material besides documents referenced within the main text.

### C.1 Telcordia Documents

- GR-303-CORE, *Integrated Digital Loop Carrier System Generic Requirements, Objectives, and Interface.*
- GR-909-CORE, *Generic Criteria for Fiber in the Loop Systems.*
- GR-1332-CORE, *Generic Requirements for Data Communications Network Security.*
- GR-3010-CORE, *Configuration Management Based on the Telecommunication Management Network (TMN) Architecture.*
- GR-3055-CORE, *Voice over Packet NGN Access Gateway Generic Requirements.*
- MC-OMS-SO-001, *Network Reliability and Risk Analysis.*
- SR-2275, *Telcordia Notes on the Networks.*
- SR-OPT-002070, *Progress On New Services, Architectures, and Technologies (SATS) - A Network Operations View.*
- SR-OPT-002253, *Progress On New Services, Architectures, and Technologies (SATS) - A Service Activation View.*
- SR-NOTES-SERIES-01, *Telcordia Notes on SONET.*
- SR-NOTES-SERIES-02, *Telcordia Notes on DWDM and Optical Networks.*
- SR-NOTES-SERIES-05, *Telcordia Notes on DSL.*
- SR-NOTES-SERIES-06, *Telcordia Notes on Fixed Wireless.*
- SR-NOTES-SERIES-10, *Telcordia Notes on Fiber-In-The-Loop (FITL).*
- TR-TSY-000398, *Universal Digital Channel (UDC) Generic Requirements and Objectives.*

## Note

All Telcordia documents are subject to change, and their citations in this document reflect the most current information available at the time of this printing. Readers are advised to check current status and availability of all documents.

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1. Click on **Basic Search** to obtain the Basic Search Criteria box
2. In the Search by Document Number field, enter the document number (e.g., GR-X-CORE), then scroll down to click on **Submit Search**
3. In the Basic Search Navigation List, select **Click for Abstract** to order an available document, or select **Click for Document** to view an available document.



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## Appendix D: Glossary

**16-Level Quadrature Amplitude Modulation (16-QAM)** — A Quadrature Amplitude Modulation is a method of combining amplitude-modulated (AM) signals into a single channel, thereby doubling the effective bandwidth. The level of the states indicates the number of states in used in the particular QAM scheme.

**16 Vestigial Sideband Modulation (16-VSB)** — 16-VSB is an advanced **Radio Frequency (RF)** modulation format for the transmission of digital television (DTV) that supports up to 38.57 Mbps of data on a 6 Mhz channel.

**Access Bottleneck** — Low data rate due to lack of bandwidth in the access network.

**Add/Drop Multiplexer** — A device that manages multichannel **Synchronous Optical Network (SONET)** or **Time Division Multiplexed (TDM)** links, picking up and assigning individual channels to a particular group of channels with a specific destination.

**Advanced Encryption Standard (AES)** — Encryption algorithm for securing sensitive but unclassified material by United States Government agencies and, as a likely consequence, may eventually become the de facto encryption standard for commercial transactions in the private sector.

**Advanced Television Systems Committee (ATSC)** — A standards organization created in 1982 as part of the Advanced Television Committee (ATV) to promote the establishment of technical standards for all aspects of advanced television systems.

**Analog Signal** — A continuously varying signal waveform. Analog signals are susceptible to interference that can change the character of the wave.

**Asymmetric Digital Subscriber Line (ADSL)** — A flavor of DSL technology that reserves more bandwidth in the downstream direction than in the upstream direction. It is advantageous for most user applications that do not need equal bandwidth in both directions.

**Asynchronous Transfer Mode (ATM)** — A method of data transportation whereby fixed length packets are sent over a switched network. It ensures reliable delivery of packets at a high data rate and is used for carrying voice, video, and data. ATM enforces QoS with bandwidth management mechanisms such as the Constant Bit Rate (CBR), Variable Bit Rate (VBR), Available Bit Rate (ABR), and Unspecified Bit Rate (UBR).

**Authentication** — The process whereby a user provides information to prove the identity that he or she claims. Often implemented using a user ID and a password prompt.

**Authorization** — It is the process of determining the permission that the authenticated user is entitled to.

**Availability** — The amount of time that a network is available for data or voice transmission, or technically, the ratio of total time that a functional unit is capable of performing its tasks during a given interval to the total time.

**Backbone** — The part of a communications network connecting the **Central Offices (COs)**. It handles the major traffic using the highest speed in the network.

**Bandwidth** — It is the capacity of a communications media. Higher bandwidth allows for the transmission of more information in a given period of time. Bandwidth is generally described either in terms of analog signals in units of Hertz (Hz), which describes the maximum number of cycles per second, or in terms of digital signals in units of bits per second (bps).

**Bit Error Rate (BER)** — This is the percentage of received bits in error compared with the total number of bits received. It is usually expressed as a number to the power of 10.

**Bridge taps** — A length of wire attached between the normal endpoints of a circuit that introduces unwanted impedance imbalances for data communication.

**Broadband Fixed Wireless Access (BFWA)** — A mix of wireless technologies that provide high-capacity access network at fixed locations.

**Broadband Network** — A large-capacity network that is able to carry multiple services at the same time, such as data, voice, and video.

**Business Management Layer (BML)** — Top layer of the **Telecommunications Management Network (TMN)** architecture that focuses on goal setting, finance, budgeting, and project planning of the network.

**Cable Modem Termination System (CMTS)** — A CMTS is a device (usually located in the **headend**) that exchanges digital signals with cable modems on a cable network.

**Cable Modem (CM)** — A cable modem is a device that enables you to hook up your PC to a local cable TV line and receive data at about 1.5 Mbps.

**Capacity** — The amount of information that a network is capable of carrying, usually measured in bits per second (bps).

**Central Office (CO)** — A telephone company facility that handles the switching of telephone calls on the **Public Switched Telephone Network (PSTN)** for a small regional area.

**Coder/Decoder (CODEC)** — Integrated circuits or chips that perform data conversion. The CODEC combines analog to digital and digital to analog conversion functions in a single chip. In personal and business computer applications, the most common use for such a device is in a modem.

**Competitive Local Exchange Carriers (CLECs)** — A telephone company that was formed after the Telecommunications Act of 1996 that made it legal for companies to compete with an **Incumbent Local Exchange Carrier (ILEC)**.

**Core Network** — The network of telephone switching offices and transmission plants connecting switching offices together. In the United States local exchange network, core networks are linked by several competing interexchange networks.

**Coverage** — The term used to describe the reach of a wireless network (or a network component).

**Customer Premises Equipment (CPE)** — An equipment in a communication system that resides within the home or office. Examples include telephones and modems.

**Data Encryption Standard (DES)** — A widely used method of data encryption using a private (secret) key that offers 72,000,000,000,000 (72 quadrillion) or more possible encryption keys.

**Data Over Cable Service Interface Specification (DOCSIS)<sup>TM</sup>** — A set of standards for transferring data via cable TV. DOCSIS is managed by the Multimedia Cable Network System, an organization formed by four major cable operators.

**Digital Loop Carrier (DLC)** — Originally, a system that allows 24 voice customers to share a single **T1** digital transmission line running between a remotely located multiplexing unit and the **Central Office (CO)**. Now it is extended to any transmission medium, especially fiber, and allows a much larger number of customers to share the same medium.

**Digital Signal** — A signal that takes one of the two values, off or on, represented by “0” or “1.” Typically, digital signals require less power and more bandwidth as compared to analog signals. Digital signals can be precisely replicated during transmission.

**Digital Subscriber Line (DSL)** — A data communications technology that transmits information over the copper wires that make up the local loop of the **Public Switched Telephone Network (PSTN)** (see also **Local Loop**). It bypasses the circuit-switch in the network and transmits the data at much faster rates than analog modem technologies.

**Digital Subscriber Line Access Multiplexer (DSLAM)** — An equipment found in telephone company **Central Offices (COs)**, which aggregates and concentrates a number of DSL subscriber lines onto a single line entering an **Asynchronous Transfer Mode (ATM)**-switched network.

**Domain Naming System (DNS)** — This is a mechanism used in the Internet to translate host computer names into addresses. A Domain Name Server (DNS) is used to convert domain names into **Internet Protocol (IP)** addresses.

**Drop** — In the context of this document, and access network in general, drop refers to the final connection between the final access network equipment and the equipment in customer’s premise. Examples of a drop network include coaxial cable, twisted copper pair, and fixed wireless transmission.

**DS0** — Digital Signal, level 0. 64Kbps in North America

**DS1** — Digital Signal, level 1. 1.544 Mbps in North America

**DS3** — Digital Signal, level 3. Equivalent of 28 T1 channels, operating at a total signaling rate of 44.736 Mbps.

**Dynamic Host Configuration Protocol (DHCP)** — A protocol that enables a server to centrally manage and dynamically assign **Internet Protocol (IP)** addresses to nodes (workstations) in a network.

**echo** — Echo occurs when voice signals are reflected back to the speaker. It is most noticeable when the delay is more than 50 milliseconds.

**Element Management Layer (EML)** — A layer in the TMN architecture that coordinates and control a subset of a **Network Element (NE)**.

**Element Management System (EMS)** — The management system that resides in the EML and controls **Network Elements (NEs)**.

**Encryption** — The conversion of data into a form that cannot be easily understood by unauthorized people. An intended recipient will be able to decrypt the data using a secret key.

**Ethernet** — Specified in the standard IEEE 802.3, ethernet is the most widely installed **Local Area Network (LAN)** technology. The most commonly installed Ethernet systems provide transmission speeds up to 10 Mbps.

**Federal Communications Commission (FCC)** — The federal organization in Washington D.C. set up by the Communications Act of 1934. It is responsible for the regulation of interstate and international communications by radio, television, wire, satellite, and cable.

**Feeder** — In the context of the **Public Switched Telephone Network (PSTN)**, feeder refers to the distribution facility between the **Central Office (CO)** and its remote **Digital Loop Carrier (DLC)** terminals.

**Fiber-In-The-Loop (FITL)** — Small carrier systems that use optical fiber for their physical transport. They are deployed within the distribution networks of individual telephone or Cable TV (CATV) customers.

**Fiber-To-The-Building (FTTB)** — FTTB brings fiber all the way to the entrance of a building. The building is typically either a commercial business or a multi-dwelling unit.

**Fiber-To-The-Cabinet (FTTCa)** — Used interchangeably with **Fiber To The Node (FTTN)**.

**Fiber-To-The-Curb (FTTC)** — The deployment of fiber optic cable from a **Central Office (CO)** to a platform serving numerous homes. The home is linked to this platform with coaxial cable or twisted pair (copper wire). Each fiber carries signals for more than one residence, lowering the cost of installing the network versus fiber to the home.

**Fiber-To-The-Home (FTTH)** — The deployment of fiber optic cable from a **Central Office (CO)** to an individual subscriber home. This is the most expensive broadband network design, with every home needing a separate fiber optic cable to link it with the **CO**.

**Fiber-To-The-Node (FTTN)** — The deployment of fiber optic cable from a **Central Office (CO)** to a neighborhood with approximately 200 to 500 households. The fiber capacity is shared among subscribers in the neighborhood via coaxial, copper, or wireless drop.

**Firewall** — A combination of hardware and software that limits the exposure of a computer or a network to attacks from outside.

**five-nines** — 99.999% availability, meaning that a user will be denied service 0.001% of the time, or 5 minutes down time within a year.

**Frame Relay** — A telecommunication service designed for cost-efficient data transmission for intermittent traffic between local area networks and between end-points in a **Wide Area Network (WAN)**.

**Frequency** — The number of cycles in an alternating current that occur within one second, measured in Hertz (Hz).

**Frequency Division Duplexing (FDD)** — A duplexing scheme that transmits uplink and downlink channels in different frequency bands.

**Frequency Division Multiplexing (FDM)** — The transmission of multiple signals simultaneously over a single transmission line by dividing the available bandwidth into multiple channels that each cover a different range of frequencies.

**Gateway** — A computer that performs protocol conversion between different types of networks or applications. In the case of supporting **Voice over Internet Protocol (VoIP)**, a gateway performs conversions between IP and traditional voice transport and signaling protocols.

**headend** — A term commonly used in **Hybrid Fiber Coaxial (HFC)** systems to refer to network backbone consisting of video transmission and reception equipment.

**High-bitrate Digital Subscriber Line (HDSL)** — A symmetric DSL technology that provides a bandwidth of up to 1.5 Mbps in each direction over two phone lines.

**Host Digital Terminal (HDT)** — This is a **Public Switched Telephone Network (PSTN)** term for headend equipment providing access network distribution. The Host Digital Terminal (HDT) is the hub site for the system integrating broadband and narrowband services including voice, video, graphics, and data.

**Hybrid Fiber-Coax (HFC)** — A network that uses coaxial cables to distribute signals to a group of individual locations, and a fiber-optic backbone to connect these groups.

**Incumbent Local Exchange Carrier (ILEC)** — A large regional telephone company that has been providing local telephone service in the United States since the divestiture of the AT&T telephone monopoly in 1984.

**Integrated Access Device (IAD)** — A network device that provides integrated voice and data interfaces.

**Integrated Services Digital Network (ISDN)** — A circuit-switched communication network, closely associated with the **Public Switched Telephone Network (PSTN)**, that allows dial-up digital communication at speeds up to 128 kbps.

**Integrated Digital Loop Carrier (IDLC)** — Access equipment which extends **Central Office (CO)** services; it connects to a **Synchronous Optical Network (SONET)** ring on the network side while providing telephony services on the subscriber side.

**Interexchange Carrier (IXC)** — A long-distance telephone carrier.

**Interference** — Unwanted signal (energy) emitted by electrical equipment or other transmitters in the surrounding area. Also used to describe physical structures that impede propagation of the signal.

**International Telecommunication Union (ITU)** — A United Nations organization that coordinates use of the electromagnetic spectrum and development of technical standards for telecommunication and radio communication equipment.

**International Telecommunication Union/Telecommunication Standardization Sector (ITU-T)** — The branch of the ITU that is responsible for telecommunication standardization.

**Internet Engineering Task Force (IETF)** — This is a large open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet. It is open to any interested individual. The actual technical work of the IETF is done in its working groups, which are organized by topic into several areas (e.g., routing, transport, security, etc.).

**Internet Protocol (IP)** — The standard signaling method used for all communication over the Internet.

**Internet Service Provider (ISP)** — An organization offering Internet access to the subscribers using computer servers connected directly to the Internet.

**ISDN Digital Subscriber Line (IDSL)** — A flavor of DSL that uses the **Integrated Services Digital Network (ISDN)** transmission data rate of 128 kbps.

**jitter** — Timing jitter is defined as the short-term variations of the significant instants of a digital signal from their ideal positions in time, where short-term implies phase oscillations of frequencies greater than some demarcation frequency. Input jitter tolerance is defined as the peak-to-peak amplitude of sinusoidal jitter applied on the input equipment interface that causes 1 dB power penalty for a **Synchronous Optical Network (SONET)** optical interface, or more than 2 ESs in a 30-second measurement interval for a SONET electrical interface, to a **SONET Network Element (NE)**. Input jitter tolerance is specified in GR-253-CORE and ITU-T Rec. G.958 and G.823. Timing jitter may arise from a number of sources with the SONET network.

**Last Mile** — See **Local Loop**.



**latency** — More commonly known as delay, an expression of how much time it takes for a packet of data to get from one designated point to another.

**Link Layer** — Also known as the data-link layer. It is the protocol layer in a program that handles the moving of data in and out across a physical link in a network. Link layer is commonly referred to as layer 2 in network hierarchy.

**Local Area Network (LAN)** — A network of linked computers and peripheral devices (such as printers, modems, and scanners). Usually LANs are used for homes, offices, buildings, or small geographical areas such as a campus or commercial complex.

**Local Exchange Carrier (LEC)** — A local telephone company. LECs provide local telephone service for phone calls originating and terminating within a single LATA.

**Local Loop** — A copper line (a twisted pair of copper wires) between a customer's premises and a telephone company's central office.

**Local Loop Unbundling** — A law introduced after the 1996 Telecommunication Act, which requires Incumbent **Local Exchange Carriers (ILECs)** to grant **Competitive Local Exchange Carriers (CLECs)** access to their (ILECs') local loops under certain conditions/agreements.

**Local Multipoint Distribution Service (LMDS)** — LMDS is a high-capacity wireless one way- and two-way communications network access technology supporting a wide range of communication services such as high-speed internet access, videoconferencing, and remote **Local Area Network (LAN)** access.

**Media Access Control (MAC)** — MAC represents a sublayer of the data link layer of the network. It is responsible for managing the access to the transmission media by multiple network entities. There is a different MAC sublayer for each physical device type.

**Media Gateway Control Protocol (MGCP)** — The MGCP, developed by Telcordia and Level 3 Communications, is one of a few proposed control and signal standards for the conversion of audio signals carried on telephone circuits [via the **Public Switched Telephone Network (PSTN)**] to data packets carried over the Internet or other packet networks.

**Microwave Systems** — Transmission system operating in the radio frequency spectrum above 890 MHz.

**Modem (M<sup>O</sup>dulator-DE<sup>M</sup>odulator)** — A device that converts digital data into analog signals and vice-versa for transmission over a telephone line.

**Modulation** — Modulation is the addition of information to an electronic or optical signal carrier. Modulation can be applied to direct current (mainly by turning it on and off), to alternating current, and to optical signals.

**MPEG-2** — It is one of the standards developed by the Moving Picture Experts Group (MPEG). It is used for coding interlaced images at transmission rates above 4 Mbps. MPEG-2 is used for digital TV broadcast and digital versatile disk (DVD).

**Multiple Dwelling Unit (MDU)** — A telephony jargon word for high-rise buildings.

**Multi-Tenant Unit (MTU)** — See **Multiple Dwelling Unit**.

**Multiplexing** — Concentrating multiple signals for transmission over a single communications line or computer channel. The two common multiplexing techniques are frequency division multiplexing, which separates signals by modulating the data onto different carrier frequencies, and time division multiplexing, which separates signals by interleaving bits one after the other.

**Multipoint Multichannel Distribution Service (MMDS)** — A method of delivering cable TV to subscribers using microwave signals.

**Network Backbone** — See **Core Network**.

**Network Element (NE)** — Elements in the lowest **Telecommunications Management Network (TMN)** layer; the **Network Element Layer (NEL)**. Refers to technology-specific network equipment.

**Network Element Layer (NEL)** — Lowest layer in the **Telecommunications Management Network (TMN)** architecture, consists of **Network Elements (NEs)**.

**Network Interface Device (NID)** — The point of demarcation between the **Local Exchange Carrier (LEC)** network and the customer premise.

**Network Interface Unit (NIU)** — “Intelligent” device that provides interfaces to run applications on end-user terminals

**Network Management Layer (NML)** — The layer responsible for the management portion of the network.

**Network Operation Center (NOC)** — A location that is responsible for the day-to-day operation of the network.

**Operations Systems (OS)** — It is the program that manages all the other programs in a computer or server.

**Optical Carrier (OC)** — A set of signal rate multiples for transmitting digital signals on optical fiber. The base rate (OC-1) is 51.84 Mbps. OC-2 runs at twice the base rate, OC-3 at three times the base rate, and so forth.

**Optical Carrier 3 (OC-3)** — A fiber optic line carrying 155 Mbps; a United States designation generally recognized throughout the telecommunications community worldwide.

**Optical Network Unit (ONU)** — Optical Network Unit is the remote equipment that provides service interfaces for the end users. It acts as the interface between customer analog access cables and the fiber facilities.

**Plain Old Telephone Service (POTS)** — The basic voice telephony service over the 0 to 4 kHz frequency spectrum. POTS is synonymous with the **Public Switched Telephone Network (PSTN)**.

**Point of Presence (PoP)** — A physical place where a carrier has a presence for network access.

**Point-to-Point (P-P)** — A network that has one-to-one correspondence between **Network Elements (NEs)**.

**Point-to-Point Protocol (PPP)** — A protocol for communication between two computers using a serial interface, usually a personal computer connected by phone line to a server. PPP is commonly used for Internet access from the PC to the ISP across the **Public Switched Telephone Network (PSTN)**.

**Public Switched Telephone Network (PSTN)** — The direct distance dialing telephone network available for public use. It is an integrated system of transmission and switching facilities, signaling processors, and associated operational support systems that customers share.

**Quadrature Amplitude Modulation (QAM)** — QAM is a modulation technique that utilizes carrier modulation. It uses a combination of phase shift modulation and amplitude modulation techniques to modulate the digital signal. QAM transforms data into a sequence of symbols that may be transmitted to a desired carrier frequency.

**Quadrature Phase Shift Keying (QPSK)** — A modulation technique that uses phase ranges to represent bit information.

**Quality of Service (QoS)** — The performance characteristics specified for an end-to-end traffic flow to satisfy the user requirement for a specific traffic type.

**Radio Frequency (RF)** — The group of electromagnetic energy whose wavelengths are between the audio and light range.

**Ranging protocol** — Technique used to estimate separations between the CMTS and customer premises (and differences among separations). Ranging protocol is crucial to the synchronization of Cable Modem's access to the CMTS.

**Reliability** — Measurement of the dependability of the system once in operation.

**Remote Digital Terminal (RDT)** — RDT is an extension of a **Central Office (CO)**, which is used to serve telephone customers at distances far away from the CO.

**RFC (Request For Comment)** — RFCs are formal documents from the **Internet Engineering Task Force (IETF)** that progress through several developmental stages of committee drafting and subsequent review by interested parties.

**Router** — A device that forwards data packets from network to another.

**scrambler** — A device used for scrambling or distorting a signal to protect content from being accessed by a non-subscriber to cable TV systems.

**scrambling** — A techniques used to protect content from been enjoyed by non-subscribers, commonly used in cable television systems.

**Service Level Agreement (SLA)** — An agreement between a carrier and customer describing measurable service quality. A service level agreement consists of one or more service level definitions, their measurement points and granularity, and the consequences for missing those requirements.

**Service Management Layer (SML) — Telecommunication Management Network (TMN)** layer that focuses on service aspects of the network such as customer access to the network, billing, maintenance, and report quality of service data.

**Session Initiation Protocol (SIP)** — An **Internet Engineering Task Force (IETF)** standard protocol for initiating an interactive user session that involves multimedia elements such as video, voice, chat, gaming, and virtual reality.

**set-top converter box** — A device that enables a television set to become a user interface to the Internet and also enables a television set to receive and decode digital television (digital television) broadcasts.

**Simple Network Management Protocol (SNMP)** — The protocol governing network management and the monitoring of network devices and their functions.

**Symmetric Digital Subscriber Line (SDSL)** — This technology provides the same bandwidth in both directions, upstream and downstream. SDSL provides transmission speeds within a T1/E1 range, of up to 1.5 Mbps at a maximum range of 12,000 to 18,000 feet from a central office, over a single-pair copper wire.

**Synchronous Optical Network (SONET)** — SONET is the United States standard for synchronous data transmission on optical media. It ensure standards so that digital networks can interconnect and that existing conventional transmission systems can take advantage of optical media through. SONET provides standards for a number of line rates up to the maximum line rate of 9.953 gigabits per second (Gbps).

**T1** — A dedicated digital communication link provided by a telephone company that offers 1.544 Mbps of bandwidth, commonly used for carrying traffic to and from private business networks and an **Internet Service Provider (ISP)**.

**Telecommunication Management Network (TMN)** — A set of international network management standards allowing as much flexibility as possible in choosing network technologies and architectures.

**Telephony Remote Access Concentrator (TRAC)** — A device that terminates and decodes the dial-up **Point-to-Point Protocol (PPP)** sessions from the cable modems before sending them to the final destinations.

**Time Division Duplexing (TDD)** — A duplexing scheme that transmits uplink and downlink data in different time slots.

**Time Division Multiplexing (TDM)** — A digital data transmission method that takes signals from multiple sources, divides them into pieces, which are then placed periodically into time slots, transmits them down a single path, and reassembles the time slots back into multiple signals on the remote end of the transmission.

**Time Division Multiple Access (TDMA)** — TDMA is a technology that allocates time slots for users to access the medium. This allows multiple users to share the system (or bandwidth).

**transceivers** — An abbreviation for transmitters and receivers.

**Transport Network** — As oppose to access networks that act as entrance to the network for end-users, transport network delivers content between information hosts and access network equipment.

**Trivial FTP (TFTP)** — A simplified version of File Transfer Protocol (FTP), which transfers files but does not require password authentication and does not provide user-directory capabilities.

**Trunks** — A line that carries multiple voice or data channel between two telephone exchange switching systems.

**Very High-bitrate Digital Subscriber Line (VDSL)** — A flavor of DSL, asymmetric in nature, that delivers from 13 to 52 Mbps downstream bandwidth and 1.5 to 2.3 Mbps upstream.

**Virtual Private Network (VPN)** — VPN uses the public telecommunications network, along with encryption and other security measures, to create a network that functions like a private data network but at a lower cost.

**Voice over Internet Protocol (VoIP)** — The technology that turns voice conversations into data packets and sends them out over a packet-switched **Internet Protocol (IP)** network.

**Voice over Packet (VoPacket)** — General term for technologies that deliver voice services over a packet-switched network, for example **Voice over Internet Protocol (VoIP)** and Voice over Asynchronous Transfer Mode (VoATM).

**Wavelength Division Multiplexing (WDM)** — The transmission of multiple signals simultaneously over a single transmission line by dividing laser wavelength into multiple channels that are transmitted over the fiber cables.

**Wide Area Network (WAN)** — A geographically dispersed telecommunications or data network that normally connects multiple **point of presences** and may interconnect different carrier networks.

**Wireless Local Loop (WLL)** — A **Local Loop** facility without wires.





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- a. Licensee withholds that amount to satisfy tax withholding requirements imposed by the country (other than the United States) in which Licensee resides or in which Licensee has accepted delivery of the Licensed Product; and
- b. Licensee furnishes a receipt issued by the withholding tax jurisdiction and certifying deposit of the withheld amount into its treasury or other tax depository to Ericsson's sole credit, or a certification on Licensee's stationery that Licensee has deposited the withheld amount into its tax jurisdiction's treasury or other tax depository to Ericsson's sole credit.

Further, to ensure the orderly processing of Ericsson tax returns, Licensee shall provide to Ericsson a summary of all amounts withheld during the year no later than ten business days after December 31 of each year addressed to: Ericsson Inc., 6300 Legacy Dr., Plano, Texas 75024, Attn: Tax Management Department.

**Governing Law.** This Agreement is a contract between Ericsson and the Licensee of the Licensed Product. This contract is to be interpreted in the federal and state courts of New Jersey, in accordance with the laws of the State of New Jersey without regard to its conflict of laws principles, and the parties consent to the jurisdiction of such courts for this purpose.

**Entire Agreement.** Licensee further agrees that this is the complete and exclusive statement of the Agreement between Licensee and Ericsson and supersedes any proposal or prior Agreement, oral or written, or any other communication between us relating to the subject matter of this Agreement.

All questions about this Agreement should be directed to:

Ericsson Inc.  
Customer Service Center (IDO)  
One Ericsson Drive  
Piscataway, NJ 08854  
Phone: +1.844.251.0201 (USA and Canada) or +1.913.241.6682 (All others)  
Email: [buss.document-info@ericsson.com](mailto:buss.document-info@ericsson.com)

**END OF TERMS AND CONDITIONS**

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