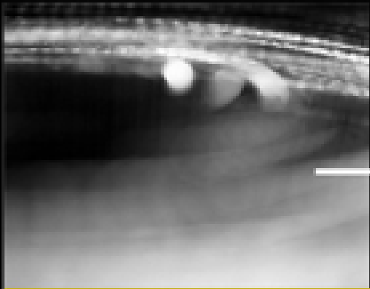

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0-07-141476-2

The material in this eBook also appears in the print version of this title: 0-07-138060-4.

DOI: 10.1036/0071414762

DEDICATION

Dedicated to my darling wife Donna and our children Eric and Scott. Their love, extreme tolerance, and support keep me going.

In memory of my late father and mother, Richard Louis and Jennie Chin Louis. I miss them both.

In memory of the late Harry E. Young, my friend, superior, and mentor.

ACKNOWLEDGMENTS

To Charles P. Eifinger (a 40-year veteran of the Bell System who retired in 1990), my friend and mentor; "The bit is on. The bit is off."

Lawrence Chu, who, thankfully, has not retired from the telecommunications business and is still around when I need advice.

Okan Azmak, after all this time he is still around to back me up.

To all of my colleagues who have influenced me through our interactions and debates.

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CONTENTS

PREFACE

Telecommunications has evolved into a highly complex series of networks with names like Local Area Networks (LANs), Wide Area Networks (WANs), wireline, wireless, in-band, out-of-band, narrowband, wideband, 2G, 3G, 4G, Multi-Frequency, SS7, CCS7, and SS6, among others. However, the various network forms can be classified as either baseband or broadband network types.

The interest in broadband has to do with gaining competitive advantage in the highly competitive telecommunications market. Many industry pundits believe that broadband technology will play a key role in the evolution of telecommunications.

INTRODUCTION

This book is a crash course about broadband technology and services. It is not a textbook. The book lays a foundation of understanding about what broadband is and what it is not. It will not cover every broadband technology, but will address the popular and up-and-coming broadband technologies.

Those who should be reading this book include: the technologist who does not understand what broadband is and needs a working understanding of the technology and issues involved and the businessman seeking to understand where investment dollars are going. The junior or mid-level engineer seeking a detailed view of broadband will have to shop for the specific book that will cover the specific technology of interest.

The book provides the tools needed to understand the broadband industry as well as giving a background on broadband so that an educational foundation can be established.

CHAPTER ONE

WHAT IS A BROADBAND NETWORK?

Broadband is the opposite of baseband. Baseband transmission is the transmission of a single signal over a transmission medium. Broadband is the transmission of more than one signal over a transmission medium. Technically a telephone conversation over a T-1 is a broadband transmission. Telephone voice conversations are multiplexed into 24 voice channels over a T span. A T-1 is capable of supporting transmission speeds of up to 1.544 Mbps.

However, today the term broadband generally is being used to describe transmission of information at speeds of 45 Mbps and higher. The term broadband services has been used generally to define high-resolution video and CD-quality audio commercial services. Figure 1.1 is a depiction of the broadband definition.

We will discuss two aspects of broadband in this book: physical technology (signaling and transmission media) and commercial service aspects. It has become commonplace to use the word broadband in the context of multimedia services. Multimedia is the combination of multiple forms of information in the communication of information. There will be more on this later in the book.

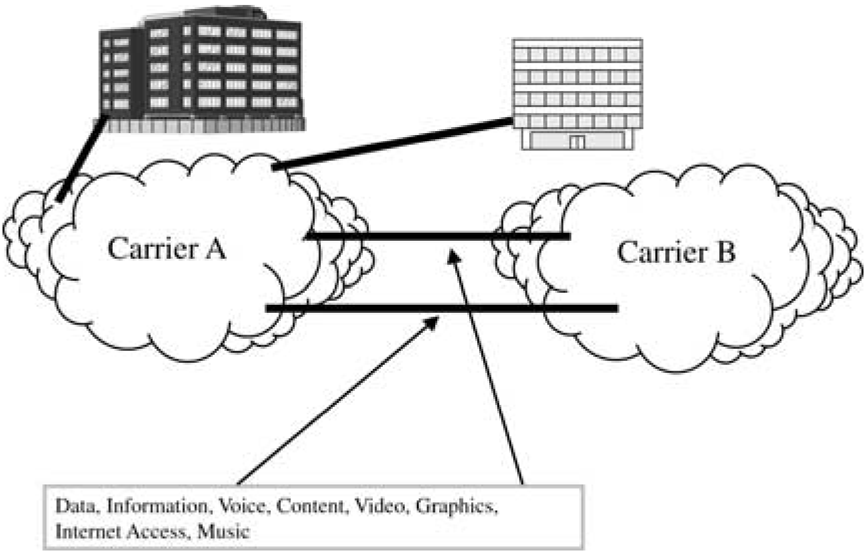


FIGURE 1.1 Broadband

In order to support a broadband transmission the media over which the transmission is occurring must be capable of doing so. Chapter 1 focuses on general issues concerning transmission media.

TRANSMISSION FACILITIES

Transmission facilities are used to interconnect the end-user (subscriber) to the network, one network to other networks, and switching or concentrating transmission points within the network. Such facilities come in many different sizes and flavors (they can support many different transmission rates). Transmission facilities are either metallic or glass. The facilities carry information in either analog or digital format. Networks are often designed with duplication of transmission facilities between two points. This practice is representative of diversity routing and is used to improve reliability.

The information carried can be transmitted in a variety of signaling formats. The signaling format is the “language” of the network and its components. The information carried by the transmission facilities is either out of band or in band. An out-of-band information stream refers to a situation in which call-control information is physically carried over one path while the actual call or content information is sent over another path. In-band information refers to the situation in which call control and call/content information is physically carried over the same path and in serial fashion.

Transmission facilities are needed to connect networks. Transmission media (also known as outside plant) can be broken down into the following basic types:

- Metallic
- Fiber optics (glass)
- Microwave (satellite and terrestrial)

Wireless carriers support a variety of radio technologies in different frequency bands. The "wireless" aspect of the wireless industry is related to local device access to the subscriber and not access between networks or even between its own network elements. To some readers this topic may seem more familiar if one refers to transmission facilities and media as "backhaul." This chapter will not touch on the "last mile," also known as the local loop, but will focus on transmission facilities that connect networks.

The biggest concern of carriers relating to transmission media is speed. Time is money, and the higher the information speed supported by the facility, the more money is made and saved. Each type of facility is capable of supporting different speeds. Transmission speeds are governed by the controlling electronics employed at both the originating end and terminating end of a transmission facility. However, medium has physical limitations associated with how much it can transmit within a certain error boundary. The following discussion will examine types of facilities used to haul volumes of information traffic between switching nodes or computing elements (data centers).

TRANSMISSION TYPES: ADVANTAGES AND DISADVANTAGES

Metal

Metallic wire (usually copper) tends to be the typical medium for DS-0 through DS-2 transmission facilities. Transmission rates will be discussed later in this book.

Metallic transmission facilities have the following advantages:

- *Durability.* In the world of wireline telephony it is not uncommon for physical "copper in the ground" or "on the poles" to last for at least 60 years.
- *Ease of Maintenance.* In some communities, the local exchange carrier (LEC) has not been to the area for decades to change out or replace the overhead or underground wire.
- *Ease of Installation.* Metallic transmission facilities can be mounted on a telephone pole or placed underground. Insulation can last for years without harm. Small animals including birds and squirrels are the greatest threat to facility insulation material. Squirrels chew on the insulation and bird "droppings" eat away at the insulation.

Disadvantages to using metallic transmission media include:

- Since this medium is made of metal, it is subject to electromagnetic interference of all kinds. This interference can reduce the quality of the transmission and ranges from radio transmissions to electrical sparking and noise caused by an electric toaster or even an electric drill. Most interference can be overcome with better electrical grounding or even signal regenerators, but there is a cost to these solutions.
- Metal ages and eventually will fail physically.
- The medium suffers from signal loss over a distance.
- It is heavy to transport. Weight and size of metallic insulated cable are transportation logistics issues.

- Metallic media require large storage areas in comparison to that which fiber optic cable needs.

Figure 1.2 is an illustration of the metallic transmission facility.

FIBER OPTICS

Fiber optics, also known as optical fiber, is still referred to as glass or simply as fiber by some. I will interchange the terms throughout the book. Fiber optics has many uses in transmission.

Generally, fiber is used in applications that require:

- *Moving data at high speeds.* Optical transmission is classified as DS4 and higher signal level. Optical rates are in their own category of formats:
  - Optical Carrier (OC)-1, 3,12, 24, 48, and 192.
    - OC-1 equates to a data speed of 51.840 Mbps
    - OC-3 equates to a data speed of 155.520 Mbps
    - OC-12 equates to a data speed of 622.08 Mbps
    - OC-24 equates to a data speed of 1244 Mbps
    - OC-48 equates to a data speed of 2488.32 Mbps

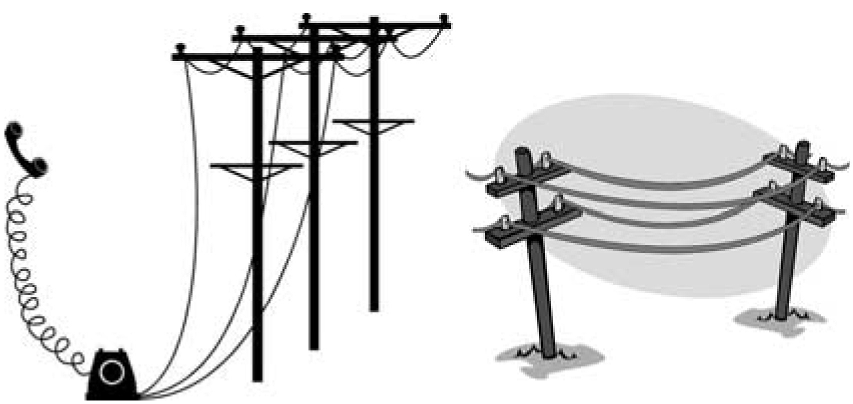


FIGURE 1.2 Metal Transmission Facilities

– OC-192 equates to a data speed of 9953.28 Mbps

- *Large bandwidth applications.* Video, Internet video and audio
- *Limited access locations.* Not all locations lend themselves to gouging out a large trench to lay outside plant.
- *Transoceanic cable.*

The advantages of using fiber optics include:

- *Nonsusceptibility to electromagnetic interference.* Glass is a nonferrous/nonmagnetic material.
- *Ground returns are eliminated.* All electrical systems need to be grounded. Grounding establishes a difference in electrical potential between electrical conductors. Light does not need to be grounded.
- *Small size.* One strand of fiber (the diameter of a human hair) can carry data at speeds in excess of 100 gigabits per second. Given the small size, carriers can lay fiber where laying (underground) metallic cable becomes obtrusive for environmental reasons, property access issues, or where there is limited room in existing underground communication cable conduit.
- *Light weight.* Not counting the protective insulation, a fiber strand is as light as a human hair.
- *Little maintenance is required.*
- *Glass does not age as fast as metal.*

Fiber optics' disadvantages include:

- *High cost for low traffic load needs.* The cost per foot for fiber is about 40 percent higher than the cost per foot for copper, so the business case to deploy fiber optics to the home does not yet exist. However, the need to create networks to meet the perceived demand for Internet access in the very near term is driving down the cost of fiber.

- *Special electronics required for the light source, light detection system, encoders, and decoders.* This means that special skill sets beyond simply hookup and cable splicing are needed for installation.
- *Susceptibility to signal attenuation (loss).* However, in comparison to metallic T-1 in which repeaters need to be installed at 1,000-foot intervals, fiber optic systems can operate with repeater distance intervals of up to 100 miles.

Figure 1.3 illustrates a fiber optic system.

Figure 1.4 is a cross-sectional view of a fiber optic cable. From a macro perspective it is not unlike a metallic wire; they both possess a conductor, insulation, and some type of outer covering.

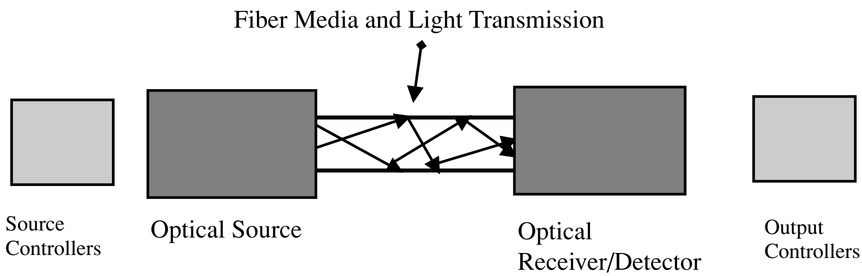


FIGURE 1.3 Fiber Optics

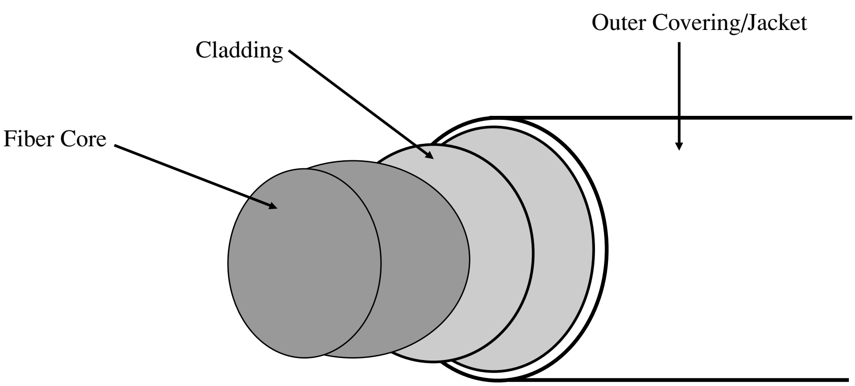


FIGURE 1.4 Fiber Cross Section

Fiber is graded as either multimode or single mode. Each one has different bandwidth and physical properties. The core of a single mode fiber has a diameter narrow enough to restrict light to one mode of travel. In other words, there is a one-way transmission facility. Multimode fiber facilities have a much wider diameter. Due to its wide diameter, multimode fiber is capable of allowing light to enter at different angles and travel through the fiber along different, crossing paths.

Multimode fiber supports more than one mode of light. Single mode fiber supports one mode. Multimode fiber has superior bandwidth properties, due to its ability to support multiple light sources, in comparison to single mode fiber. However, single mode fiber is superior since it can carry the optical transmission further than multimode can without the need for regeneration. It can also support higher bandwidth transmissions.

The word “mode” can be confusing; instead think of “type.” Single mode fiber is a fiber that supports a single type of light or a single frequency of light.

Figure 1.5 illustrates the advantages and disadvantages of a fiber optic system.

MULTIPLEXING TECHNIQUES

Wave Division Multiplexing (WDM) is a fiber optics multiplexing technique that can dramatically increase the optical transmission media. This will be discussed in detail later, but, briefly, the technique enables a single fiber optic strand to accommodate multiple light signal frequencies rather than one single frequency.

A GROWING PROBLEM: POLE SPACE/CONDUIT SPACE

There is a growing problem in the telecommunications industry, including the Internet business: lack of telephone pole space. The majority of telephone poles in active service range in height from 30 to 35 feet. The large number of new carriers in the market today has resulted in competition for space on telephone poles. Telephone poles are actually getting taller and

Fiber Advantages:

- Nonsusceptibility to electromagnetic interference.
- Ground returns are eliminated.
- Small size—one strand of fiber (the diameter of a human hair) can carry data at speeds in excess of 100 Gigabits per second.
- Light weight
- Low maintenance requirements
- Glass does not age as fast as metal.

Fiber Disadvantages:

- Expensive for low traffic load needs.
- Requires special electronics for the light source, light detection system, encoders, and decoders.
- Susceptible to signal attenuation (loss) fiber optic systems can operate with repeater distance intervals of up to 100 miles.

FIGURE 1.5 Fiber: Advantages and Disadvantages

one now sees new telephone poles as high as 40–45 feet. Figure 1.6 is an illustration of telephone pole mechanics.

Conduit space became a problem during the late 1980s. Cities and even small towns thread metal and glass through an underground conduit, but digging up a street, road, or sidewalk to install new conduit is expensive. Existing conduit has become prime real estate. This problem is depicted in Figure 1.7.

Despite the vast number of telecommunications carriers going out of business, the industry is not dead. The number of new telecommunications opportunities for service provisioning will grow. There will be new carriers (service providers to the end-user). The industry is going through a number of changes and the serious long-term players will be back in force.

Terrestrial microwave was used in the 1960s for nationwide connectivity. Satellite transmissions for overseas connectivity also started gaining a foothold in the industry during the 1960s. However, microwave transmissions are now heavily used for network connectivity. Wireless transmissions ease the burden of conduit and overhead wire issues.

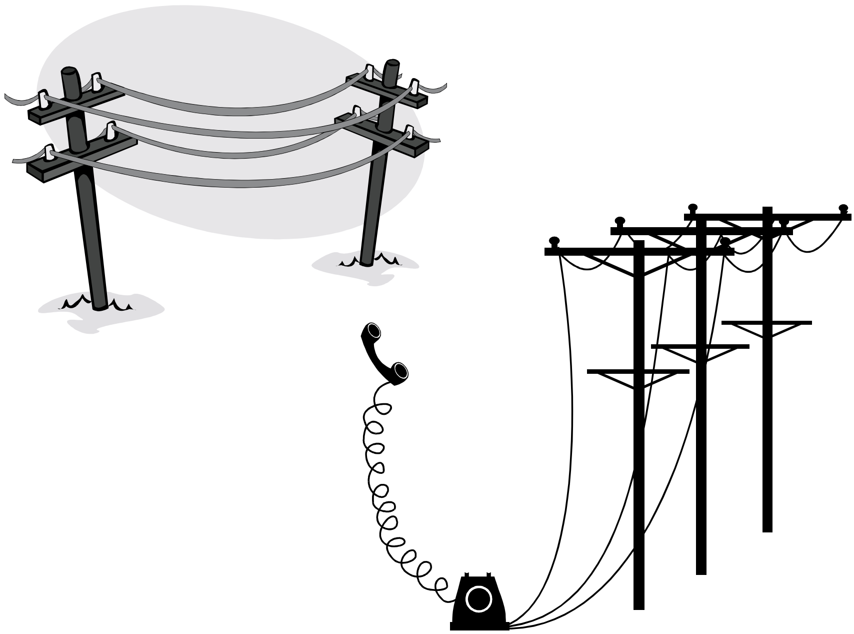


FIGURE 1.6 The Telephone Pole—Overhead Wire

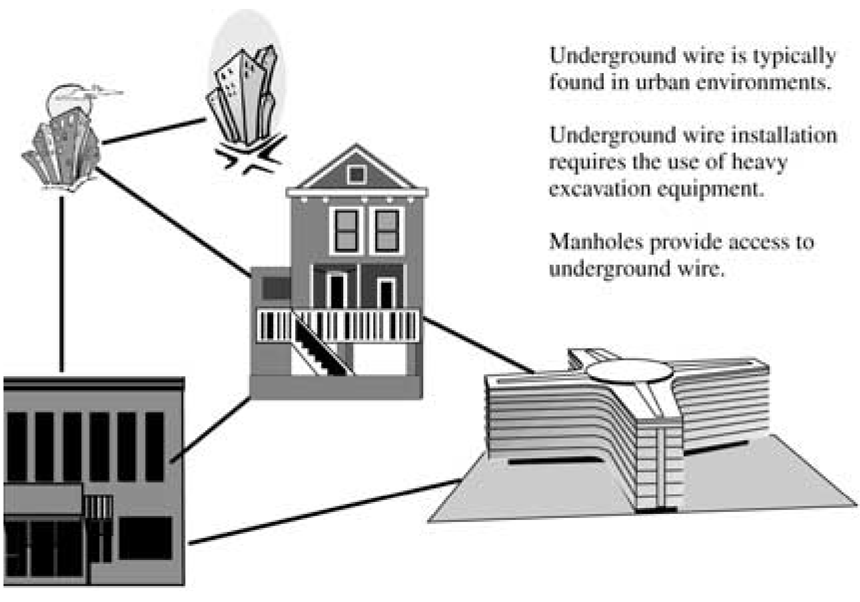


FIGURE 1.7 Underground Wire

MICROWAVE/RADIO (CELLULAR, PCS, ETC.)

Radio energy transmission in the 1.3 GHz range and higher is categorized as microwave. (Microwave transmissions in the 2.4 GHz range cook food.) There are two types of microwave transmissions, terrestrial and satellite. We will focus on terrestrial microwave network-to-network issues first so that you can more easily draw comparisons between metal and optical transmission media capabilities.

Terrestrial microwave transmission consists of line-of-sight transmission through the atmosphere using focused microwave energy. Microwave antennas can be seen in all areas of the country and typically are mounted either on their own towers or on top of tall buildings. Most microwave antennas are mounted at least 300 feet high so that line of sight can be established over treetops.

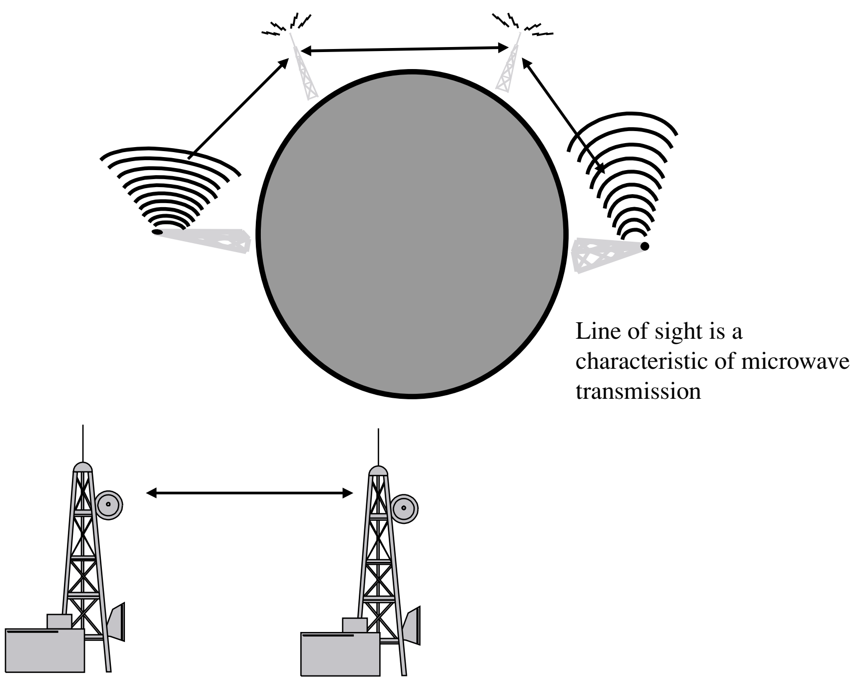


FIGURE 1.8 Microwave Transmissions

Line-of-sight refers to the transmission and reception visibility between microwave stations. The distance between stations is a function of tower height, terrain cover (i.e., buildings, trees, and water), topology (mountainous, flat, desert, water, etc.), the earth's horizon, and atmospheric conditions. The typical distance between microwave stations is approximately 25–30 miles. The tower must be able to "see" over the treetops or past buildings. Distances depend on the frequency bands in which the transmission occurs.

Microwave energy can be focused into tight and narrow beams, but a line-of-sight is required in order to ensure reception between antenna stations. The microwave energy can be absorbed by any number of objects, both animate and inanimate. The absorption will result in significant signal degradation. Microwave transmissions for network connectivity usually occur in the 4GHz, 6GHz, and higher bands. Transmissions in the 1.3 GHz and 2GHz bands support cellular and Personal Communications Service (PCS) network-to-handset communications.

Figure 1.9 illustrates line of sight.

Microwave transmission has a variety of telecommunications applications:

- Communication (e.g., military)
- Linking wireless carrier cell sites in a wireless carrier network (i.e., backhaul)
- Linking within wireline carrier networks between geographic areas. Rather than laying cable across an expanse of land at considerable cost, one can use a microwave "shot" to cross "the divide." The cost can be unending bickering with landowners or nearly endless negotiations with the local boards of several different towns. Another cost is that of the physical cable, whether it is fiber or metallic.

Like fiber optics and metallic cable, microwave has its own advantages and disadvantages, which are technical, operational, and financial in nature.

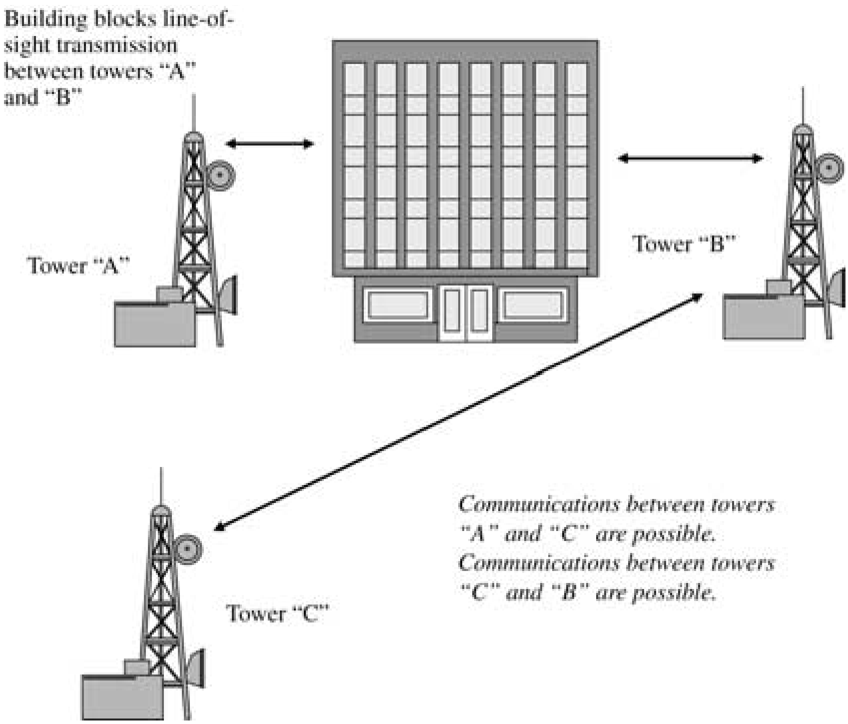


FIGURE 1.9 Line of Sight

Microwave transmission advantages include:

- Low-cost when compared to fiber optics and metallic cable. The cost of physical transmission media has two different facets: political and financial.
  - *Political.* Local zoning boards can prevent the laying of physical transmission facilities for a variety of reasons, which might include damage to the environment and damage to public and private property.
  - *Financial.* Unless the carrier can claim right of way, it will be paying private landowners monthly or annual charges for the use of the land it is crossing. This can result in paying numerous high rents or leasing fees to numerous landowners; one can overcome this potential real estate management problem by using microwave. Another cost is that of

constructing, laying, and burying cable in harsh environments that require protection for the facility and to ensure the safety of the facility construction crews.

- Large bandwidth that can support a variety of voice, video, and data applications. Microwave transmission is classified as DS3 and higher signal level.
- Ability to bridge harsh terrain where laying cable is nearly impossible. Such terrain can include mountains, desert, canyons, valleys, dense forest, and bodies of water. Safety of the personnel is always an issue, however, proper physical installation of cable of any kind may require crossing terrain that will demand costly construction and demolition methods.
- Repeater spacings of 25 to 30 miles, as opposed to repeater spacings of 1,000 feet for a typical T1 span.

The disadvantages of microwave transmission are to some extent the flip side of the advantages just described:

- *High cost.* The cost of deploying a microwave system can be described in two ways: political and financial.
  - *Political.* Placing towers, especially those with the labels of cellular, PCS (Personal Communications Services), radio, and microwave, can bring outcries from local community or town zoning boards and environmental groups. The towers (specifically, what the antennas are transmitting) will be tagged as being unsightly, environmentally damaging, or health hazards.
  - *Financial.* Some, but not all, landlords may decide to charge the carrier high rent or leasing fees for the towers and sometimes just the antennas. Land, rooftops, and building facades are all used to support towers and antennas. Sometimes the antennas are just installed on building facades. Regardless of installation location, it is all real estate that can be rented or leased.
- *Lack of security.* When large bandwidth can support a variety of voice, video, and data applications, unfortunately, the

transmissions are not necessarily secure unless encoding is performed.

- *Weather-related problems.* The transmissions are subject to the whims of weather; variations like rain, fog, warm air, cold air, hot earth, cold earth, warm earth, cool earth, bodies of water, or any combination of these. The solutions are either higher towers or towers nearer to each other.
- *High installation cost.* Microwave transmission can bridge harsh terrain where laying cable is nearly impossible. Harsh terrain can include mountains, desert, canyons, valleys, dense forest, and bodies of water. Safety of the personnel is always an issue. Proper physical operation of remote microwave stations will require environmentally controlled enclosures, electrical power, heating, ventilation, air conditioning, storage for tools, and access security for the station. If the terrain is harsh, there is a high probability the ambient environment (i.e., weather) is also harsh.

Figure 1.10 is a rendering of the advantages and disadvantages of the terrestrial microwave system.

Microwave transmission can also be viewed from a nonterrestrial perspective—satellite transmission. This is growing in popularity as a medium to haul information around the globe but is not used in any significant fashion for the public telecommunications systems in use. Satellite transmission will be addressed in later chapters as a technology and business opportunity.

WIRELESS TRANSMISSIONS (CELLULAR, PCS BANDS, LMDS, ETC.)

Users (customers) are purchasing a variety of wireless handsets that operate at a variety of frequency ranges. These frequency ranges or bands are used by cellular carriers, PCS carriers, and dispatch services. The frequency bands include 700 MHz, 800 MHz, 900 MHz, 1800 MHz, and 1900 MHz. There are even consumer-oriented wireless services in the 24-GHz band. Globally, there have been numerous radio spectrum auctions

Microwave transmission advantages are:

- Low cost option when compared to fiber optics and metallic cable
    - Politically more acceptable than other alternatives
    - Financial: Avoids construction in hazardous environment issues
- Large bandwidth can support a variety of voice, video, and data applications
- Can bridge harsh terrain where laying cable is nearly impossible
- Large repeater spacing

Disadvantages of microwave transmission are:

- High cost
    - Political: Placing towers can bring outcries from local community/town zoning boards and environmental groups
    - Financial: Potential for high rents/leasing charges
- Transmissions are not necessarily secure unless encoding is performed
- The transmissions are subject to the whims of weather
- Harsh terrain usually equates to harsh weather, which can cause personnel safety issues

FIGURE 1.10 Microwave: Advantages and Disadvantages

intended to support the creation of new wireless services and the proliferation of existing wireless services.

These frequencies have been used to support network-to-handset connectivity, not network-to-network connectivity. Terminal device-to-network connectivity will be discussed later.

WIRELESS TRANSMISSION RANGES

Transmission ranges for wireless vary. Factors that affect the range of a wireless transmission are:

- Transmitted power (effective radiated power [ERP])
- Antenna height
- Ambient environment of the operating area
    - Temperature
    - Humidity
    - Buildings that may act as obstacles or reflective surfaces
    - Solar radiation

- Other radio energy transmission sources and their transmitted frequencies
- Frequency of the transmission

A good rule of thumb to use to determine range is to assume an ERP of 1 watt, flat terrain, no foliage (i.e., trees), and an antenna height of 10 meters. See Table 1.1.

TABLE 1.1 Frequency and Transmission Range

FREQUENCY	RANGE
800 MHz–6 GHz	Maximum of 45 kilometers
6–12 GHz	Maximum of 30 kilometers
12–20 GHz	Maximum of 5 kilometers
20–30 GHz	Maximum of 2 kilometers

This represents an ideal environment for an analog transmission. You should understand that in an analog transmission environment frequency and wavelength are inversely related. The higher the frequency, the shorter the wavelength. See Figure 1.11 for an illustration of the relationship between frequency and wavelength.

In an analog transmission, physical obstacles can block a signal. Given the parameters above, the longer the wavelength, the easier it is for a radio transmission to pass through a wall. The shorter the wavelength, the harder it is for a transmission to pass through a wall, but the easier it is for the transmission to be reflected. Yet, the more the power transmission levels increase the easier it becomes for a high frequency transmission to penetrate obstacles. Digital transmissions suffer from the same problem. Even though the waveform is digitized, it is still radio energy. The digitized radio energy is a waveform that has been sampled and digitized (0s, 1s, and –1s being transmitted at a certain rate), therefore it is still electromagnetic radiation that can be blocked. High-frequency transmissions have short wavelengths. The shorter the wavelength, the closer the radio energy pulses approximate the physical density of most objects. Therefore, the physical object can present an obstacle to high-frequency transmissions.

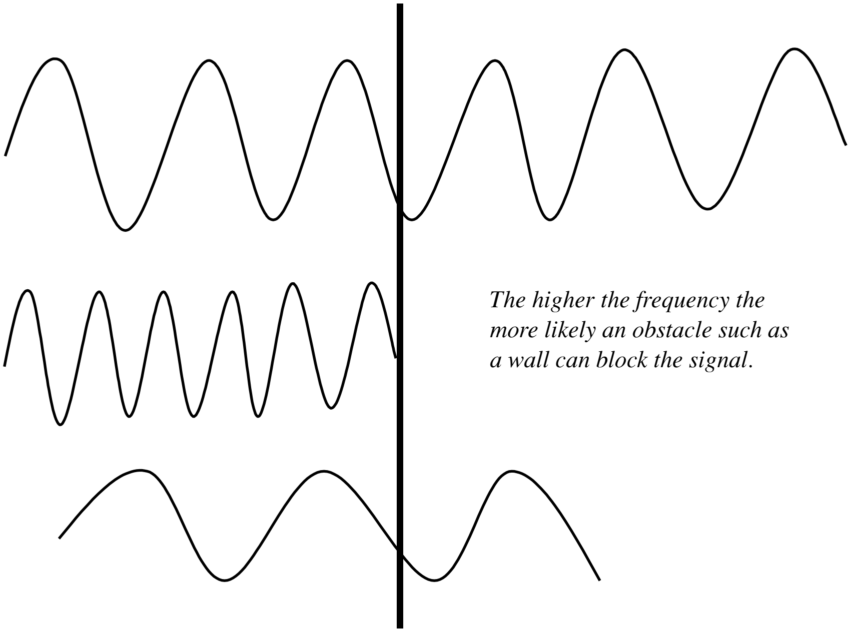


FIGURE 1.11 Frequency versus Wavelength

Digital transmissions have fewer problems with ambient environmental electromagnetic noise, but terrestrial microwave transmissions are largely analog. Digitizing the transmissions for network-to-network connectivity and mobile handset communications has greatly increased. Digital transmissions can suffer interference from other digital transmissions.

What I have offered is not a scientific or technical explanation, but a quick measuring tool. When you hear that a high-frequency transmission is the basis of a system, you should understand that all the variables I have described have an impact on transmission and reception of the signal and ultimately the physical network design. For example, the parameters for a system may be:

- Transmission power of 0.500 watts
- Urban environment—very dense
- Services—voice and data

Based on these parameters, the following will come to mind to the cautious investor:

- Lots of antennas
- Lots of real estate for the antennas
- Lots of landlords to pay monthly rent to
- Probably a high cost for installation; most urban environments require expensive technicians

This is a quick reality check for the cost-conscious executive or investor. Remember, the cost of the system often is not in the technology but in the deployment of the technology. Figure 1.12 highlights these issues.

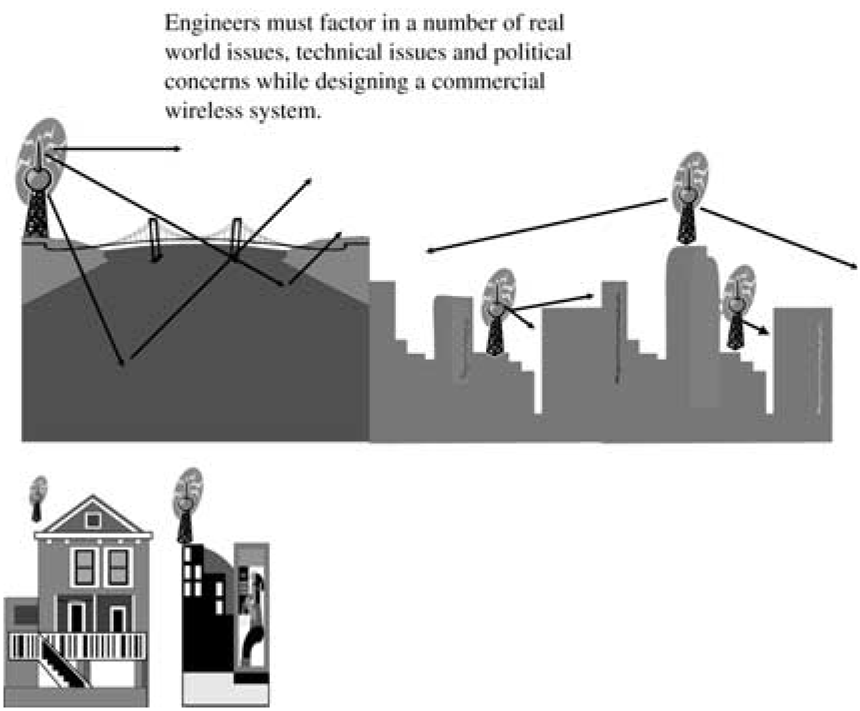


FIGURE 1.12 Deployment versus Technology

EVALUATING TRANSMISSION FACILITIES

Microwave, fiber, and metallic cable each have advantages and disadvantages. The only way to evaluate the necessity to use any of these media or a combination of them is to perform a cost–benefit analysis. The analysis should seek to answer the following questions:

- What kind of data is the carrier transporting?
- What are the data transmission speed requirements? This can also be equated to the quantity of data expected to be transmitted.
- What level of security is required for the data?
- Where does the data need to be transmitted?
- What other data will the network transit?
- Are there time-of-day and day-of-week transmission requirements?
- Are there any seasonal peaks or fluctuations in traffic volume?
- What signaling protocol will be used to transmit the data?
  - Certain protocols have speed limitations. If the data used is limited to a certain type of information traffic, there may be high rather than lower speed requirements.
- Does the transmission medium need to be fractionalized in any way?
  - If so then how many channels need to be supported?
- What are the various cost components associated with providing a transmission facility that will support the needs of the network up to this point?
  - These cost components may include real estate rent; facility expenditures such as light, heat, and air conditioning; or even facility equipment cage leasing or purchase. The point is to identify every cost of installing, operating, and maintaining that facility.
- Wireless engineers will also perform a path analysis, known as a link budget. Link budgets address operating issues such

as transmitted power, antenna design, noise, and bit error rates. These wireless design issues will also play a role in a wireless carrier's decision.

- What is the overall cost of the alternatives being examined? This total picture includes fees, rents, and leasing fees paid to landlords.
- What do the financials of the business plan look like? The technology component will play a key role in the financial analysis.

Each of these questions has a technical as well as a financial component. Many might think that the financial analysis issues are primarily associated with switching or routing equipment, but that is not so. Running a service provider is about two things: providing service and providing service cost-effectively. What often drives a carrier are the financial budgets approved and not the perfect technical solution. Figure 1.13 illustrates important points regarding the evaluation of transmission facilities.

The challenge to balance cost and functionality is not an easy task but one that must be addressed.

- What kind of data is being transported?
- What are the signaling requirements?
- How much data will be transported during a given time period?
- How much will it cost?
- How much equipment will we need?
- What are the time deadlines?
- Where is the transmission facility being installed?

Who
What
When
Where
Why
How Much

FIGURE 1.13 Evaluating Transmission Facilities

TRANSMISSION MEDIA: DATA RATES

Transmission data rates can often be confusing. Many industry players will use words like "data rate," "data speed," "data volume," and "bandwidth," which all referring to the same thing: the volume of data transiting across the transmission medium over a given fixed period of time, typically in terms of "bits per second." Speed is the major differentiator for the various transmission media.

Time is money and the higher the information speed supported by the facility, the more money that is made and saved. A transmission facility's sole function is to serve as the distribution medium for information.

The most common transmission facility today is the T-1. "T-1" refers to a specific type of telephone transmission equipment used to support digital voice transmission. The T-1 facility is a metallic media that offers two-way connectivity at an information speed rate of 96000 Hz. T-1 facilities support analog voice inputs that have been multiplexed into 24 channels.

Before T-1, voice was transmitted over solid copper wire—the conversations were baseband; that is, one strand of wire for every conversation. At the turn of the 20th century, transmission facilities of this type resulted in towns and cities being overwhelmed with overhead wires and telephone poles.

In the 1950s, a multiplexing technique known as Frequency Division Multiplexing (FDM) enabled service providers to take the single copper wire and make use of its full bandwidth. In other words, multiple voice conversations were transmitted over specific frequency ranges; conversation 1 is transmitted over frequency range 0–4000 Hz, while conversation 2 is transmitted over frequency range 4000–8000 Hz, and so forth. There were two analog transmission facility types used in the 1970s and earlier: the L-carrier system and the N-carrier system. Both supported 24 channels.

However, analog amplification and multiplexing brings one problem: noise. The N and L transmission facilities were susceptible to nearby ambient electrical signals created by electrical motors, electrical power lines, other communications facilities, and any other source of electromagnetic radiation.

These unwanted signals are called noise. The noise problem was addressed when the telecommunications industry developed digital transmission, resulting in the T-1. Digital transmission addresses the problem caused by analog transmission: The analog signal can assume almost any value. On the other hand, a digital signal can only assume two values; 0 or 1. (You should note that the name "L-carrier" referred to a specific transmission facility type and the associated repeaters used by the Bell system to carry long haul analog traffic. The "N-carrier" facility was used in the local telephone company interoffice networks.)

The T-1 was the first digital transmission facility. Over the years, the use of the T-1 term became corrupted to refer a transmission rate, specifically DS-1 rates, rather than to the name of an equipment type.

At this time, a brief description of analog and digital is in order.

ANALOG VERSUS DIGITAL

Analog can be defined as an electromagnetic or audio signal that can assume any value. Digital can only assume discrete values within the signal.

A voice, sound, or electromagnetic signal can be pictorially drawn as a waveform. Figure 1.14 describes the analog and digital waveforms.

The analog waveform can assume any shape. The shape can be irregular or smooth and symmetric on both sides of the axes. The dots in figure 1.14 represent discrete values or points on the waveform. These points represent a digital sample of the waveform. The analog waveform is sampled using a technique like Pulse Code Modulation (PCM). PCM works like this:

1. The analog signal is sampled or looked at by the system at a rate of 8,000 times per second, which is twice the rate of the information contained in the analog signal. This system is referred to as the modulator. The modulator sends each sample out through the network. Each sample has a discrete value that can be overlaid on the original analog waveform.

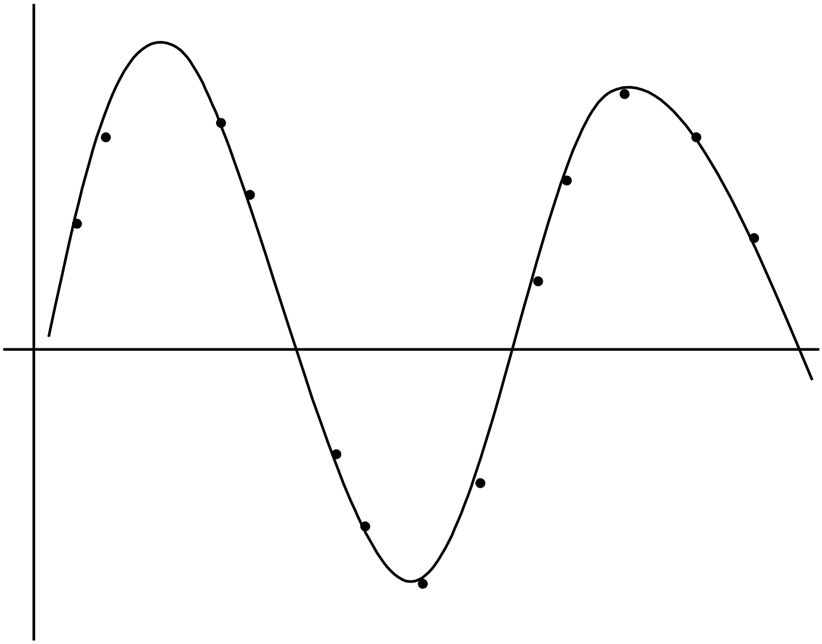


FIGURE 1.14 Analog versus Digital

When you assemble all the pieces the result looks like a "connect-the-dots" picture of the original waveform.

2. The value or height of the signal sample is then converted to a binary (digital) value by an encoding device. The result is an 8-bit binary word. The whole process results in the analog signal's being converted into a digital signal of 64,000 discrete bits per second.

A single voice transmission requires 300–3300 Hz worth of bandwidth. Taking this into account, we find that when the voice is converted to a digital equivalent the bandwidth required is 64,000 bits per second. When you implement this over a T-1, you can still place 24 analog channels on the T-1. In the digital environment, each channel's data rate is 64,000 bits per second. This will become clearer in the modulation section of this book.

The older term for bits per second was baud rate. Baud is the number of times per second that the carrier signal shifts value. For example, a 1,200 bit-per-second modem is said to be running at 300 baud. This modem would be moving 4 bits per baud ($4 \times 300 = 1{,}200$ bits per second).

At 24 channels, a T-1 is capable of a total data rate of 1,536,000 bits per second plus 8,000 bits per second for control and synchronization, resulting in a total data rate of 1,544,000 bits per second or 1.544 Mbps. The maximum number of simultaneous conversations that can be carried over a T-1 facility is 24. This is the standard rate in North America, Japan, and Australia. In Europe and other ITU countries, 30 voice channels and two signaling channels are multiplexed at a rate of 2,048,000 bits per second. The T-1 is used to support transmission of information between switch locations.

Today the term "T-1" has become overused; instead of referring to the facilities capacity the term is used to refer to the digital transmission rate of DS-1. The term T-1 is often interchanged with the term DS-1. The DS-1 supports a digital version of the 24 analog channels supported by the T-1.

The current digital transmission rates are shown in Table 1.2.

TABLE 1.2 North American Digital Transmission Rates

Signal Rate	Bits per Second	Number of Channels	Analog Equivalent
DS-0	64,000 bps	1	none
DS-1	1,544,000 bps	24	T-1
DS-1C	3,152,000 bps	48	T-1C
DS-2	6,312,000 bps	96	T-2
DS-3	44,736,000 bps	672	T-3
DS-4	274,176,000 bps	4032	T-4

Once a telecom provider goes past the DS-3 level, it typically moves into the realm of optical fiber. This shift into glass occurs simply because it is more economical.

NETWORK SIGNALING

There are many types of network signaling. For instance there is signaling that supports:

- Network-to-terminal device
- Terminal device-to-terminal device
- Closed user groups
- Network-to-network

In this section, we focus on network signaling to establish a baseline understanding.

Network signaling is the language by which we communicate with other service providers and by which we communicate with network elements within our own network. The key component of network interconnection is the signaling protocol. There are two dominant signaling protocols used in North America for the mass market: Multi-Frequency (MF) and Signaling System 7 (SS7). Later chapters will address up-and-coming signaling protocols in the communications industry.

You can use one set of network-to-network signaling protocols and simultaneously use a different set of signaling protocols for terminal device communication. Networks are no different from people when communicating with one another: there are a variety of accents, dialects, and languages. Figure 1.15 is a representation of network signaling.

Network signaling protocols lie at the heart of a transmission medium's capabilities. Without a signaling protocol, the transmission media is nothing more than a pipe without anything in it; there is much potential carrying power but nothing is being transported.

The MF and SS7 protocols are the primary late 20th century and early 21st century signaling protocols used by the wireline and wireless service providers of services to the mass market. SS7 and MF signaling are not capable of supporting broadband multimedia applications but are capable of supporting voice and low-speed data applications.

SS7 is not some broken-down, misplaced signaling protocol. SS7 revolutionized the network:

- Transmission facilities for bearer traffic no longer needed to be allocated until the call was answered, thereby increasing the utilization of resources.

Network architecture supporting SS7 signaling

Signaling is the language of networks and network elements.

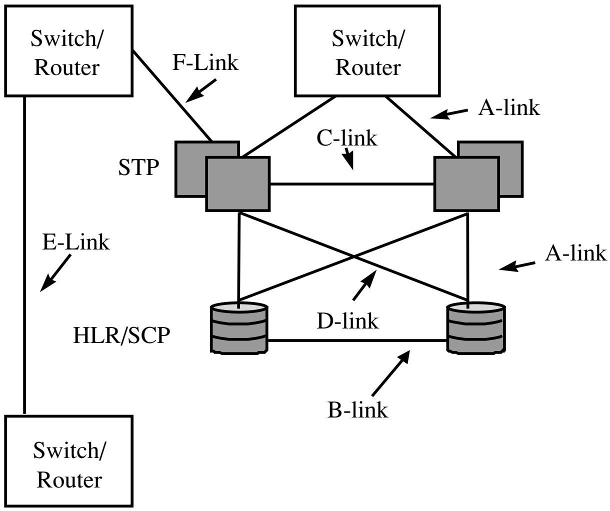


FIGURE 1.15 Network Signaling

- SS7 made intelligent services easier to develop and deploy. For the first time, services could be developed and deployed using only software at the switch's maintenance terminal.

MULTI-FREQUENCY SIGNALING

Before Multi-Frequency (MF) signaling, the pulsing of digits of the called number conveyed address information. A single digit could require up to 10 pulses (interrupting electrical current flow). It takes 1 second for 8 to 12 pulses to be transmitted. When you include the pauses between digits (about 500 milliseconds) a single 10-digit telephone number could take several seconds to transmit. Few subscribers want to wait that long for their calls to be completed. MF signaling uses tone pulsing in the voice frequency range. MF signaling (tone pulsing) transmits digits by combining 2 of 6 frequencies.

MF frequency pulsing of a 10-digit number takes about the same amount of time as it takes to transmit the single digit in older signaling systems. MF signaling utilizes tones in the

700–1,700 Hz range. When an MF tone is transmitted (representing a digit), two frequencies are sent simultaneously for each digit.

Table 1.3 illustrates the MF signaling code. Note that supplementary tones called KP and ST are also supported. KP stands for request for Key Pulsing sender and ST stands for the completion of keying and the start of circuit operations.

TABLE 1.3 MF Frequencies and Digits

DIGITS	FREQUENCIES (HZ)
1	700+900
2	700+1100
3	900+1100
4	700+1300
5	900+1300
6	1100+1300
7	700+1500
8	900+1500
9	1100+1500
0	1300+1500
KP	1100+1700
ST	1500+1700

MF pulsing existed before the electronic switch. It was originally supported in the electromechanical telephone-switching environment, involving manual operations and electromechanical equipment. Originally, a manually operated switchboard initiated MF pulsing. The operator would select an idle trunk, then press the KP button on the keyset to signal the distant sender or register link equipment to connect to an MF receiver. The MF receiver resides in the terminating switch. The S lamp on the keyset would light when the terminating equipment was ready to receive the MF pulses. After the digits of the called number were keypulsed, the operator pressed the ST button, which indicated the end of pulsing and also disconnected the keyset from the operator's cord circuit.

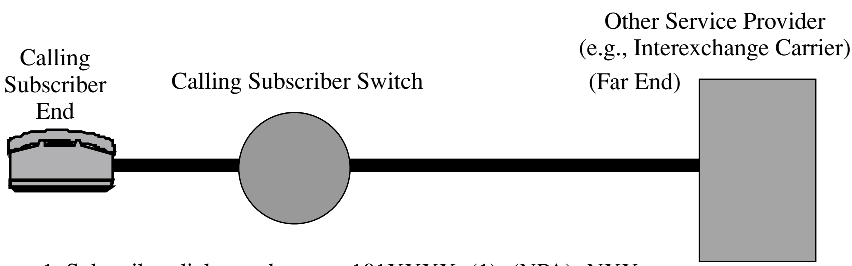
The introduction of common-control landline switches (aka central offices) such as electronic switching and electromechanical switches (e.g., crossbars) required that MF signals be transmitted by MF outpulsing senders. The terminating switch (called-party's switch) contained equipment called MF receivers. These were connected to the incoming sender or register link circuit. As you may have gathered MF pulsing is a high-speed activity. MF outpulsing only occurs during the period when a connection is being established.

See Figure 1.16 for an illustration of how an MF call is made and processed.

The call illustrated in Figure 1.16 involves an Interexchange Carrier. Signaling sequences in the MF world are different for each type of call. The point of the diagram is to illustrate the serial nature of the sequence. In the world of Common Channel Signaling (CCS), the sequence is made up of messages (bits of data) as opposed to tones.

COMMON CHANNEL SIGNALING (CCS)

Common Channel Signaling (CCS) is a type of out-of-band signaling. The signaling used in MF pulsing is circuit-associated or



1. Subscriber dials number, e.g. 101XXXX+(1)+(NPA)+NXX
2. Trunk seized calling subscriber's switch
3. Far end sends back Wink
4. Calling subscriberís switch sends KP+II+ANI+ST
5. Subscriber completes dialing the rest of the telephone number XXXX
6. Calling subscriber's switch sends KP+(0)+7 or 10 digits + ST
7. The far end sends back an Acknowledgment Wink
8. The far end sends back Answer Supervision
9. Conversation

FIGURE 1.16 Multifrequency Call

in-band signaling. While MF pulsing is tone based, CCS is actually a computer message–based signaling protocol. The MF signals used to set up facilities between the called and calling party occur on the same physical path as that of the conversation. In out-of-band signaling (in this case CCS), the signaling associated with setting up the facility path for the conversation is different from the conversation path.

The architecture illustrated in Figure 1.17 shows a Common Channel Signaling system.

Common Channel Signaling, specifically ANSI Signaling System 7 (SS7), is the dominant form of CCS used in North America. SS7 is also being installed in all wireless systems. SS7 is the basis for all intelligent network platforms. Wireless systems (cellular and PCS) are installing enhanced service platforms, many of which require SS7 as the basic signaling protocol for their networks. SS7 is not the fastest network signaling protocol but it is the most robust and mature out-of-band signaling protocol that exists to process calls and enable communication between network entities.

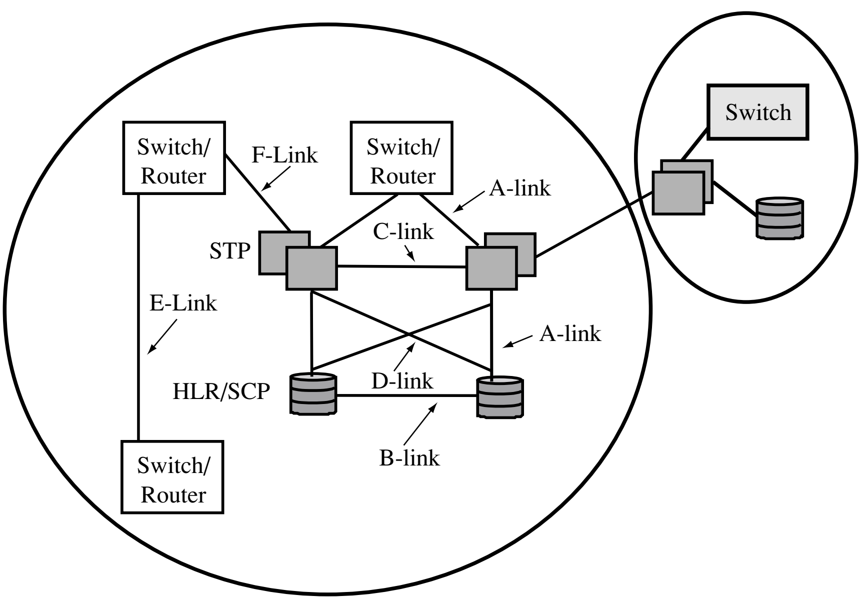


FIGURE 1.17 CCS—Signaling System 7

COMMON CHANNEL SIGNALING (CCS) NETWORK ARCHITECTURE

The SS7 network architecture consists of a set of network elements generally referred to as nodes. These nodes are also called Signaling Points (SPs). A switch is an SP. These SPs are interconnected via point-to-point signaling links.

Figure 1.18 illustrates the basic SS7 architecture.

The signaling links shown are:

- *Access link (A-link).* Used for switch-STP signaling connections and STP-HLR.
- *Bridge link (B-link).* Used to connect STP-STP in other networks.
- *Cross link (C-link).* Used to connect diverse STPs of the same hierarchical level.

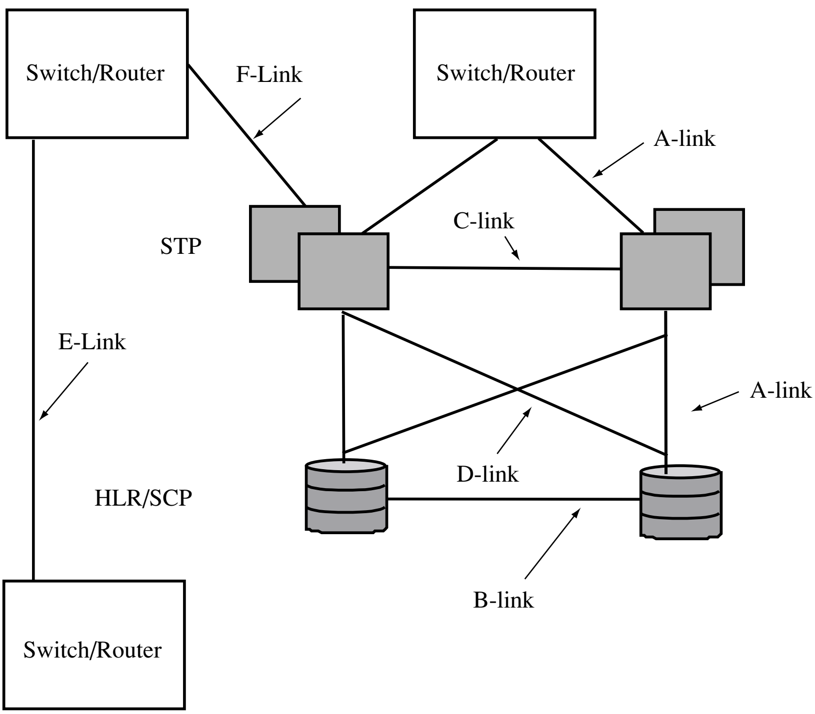


FIGURE 1.18 SS7 Architecture

- *Diagonal link (D-link).* Used to connect STPs of different hierarchical levels or diverse STP-HLRs/SCPs combinations.
- *Extended link (E-link).* Links between switches and non-home STPs.
- *Fully Associated (F-link).* Optional links between switches.

Today, carriers prefer SS7 over MF signaling. However, carriers are in the early stages of transition to a newer out-of-band signaling protocol known as Asynchronous Transfer Mode (ATM). There will be more on ATM later in this book.

The following minimum information is required between the service provider network and other SS7 networks: point codes (full point codes and cluster point codes), subsystem numbers, signaling link codes, timer values, signaling link test, congestion threshold, routing priority, and global title translation.

The Signal Transfer Point (STP) relays messages at the network layer between switches. STPs are deployed in mated pairs. The STPs are a crucial part of SS7 network design. STPs contain the routing templates used by carriers to route calls. These templates are decision matrices.

The Service Control Point (SCP) is the database that contains the subscriber feature and service profiles. SCPs can also provide assistance in the routing of a call.

The SS7 protocol is comprised of layers of functions and tasks. The protocol is similar to an architecture established by the International Standards Organization (ISO) called the Open System Interconnection (OSI) architecture.

When communication is desired among computers (switches are nothing more than computers) from different manufacturers or vendors, the software development effort can be very difficult. Different vendors use different data formats and data exchange protocols that do not allow computers to communicate with one another. The OSI model is an engineering model that breaks everything down into very simple and discrete tasks or layers.

The OSI model was actually created after SS7. The OSI model was developed by the ISO for use in a computing environment. It is similar to SS7 because some of the concepts behind switching information and layering functions are the same in the telecommunications world.

The two models do not align perfectly because of the different times at which they were developed and to some extent the perspective with which they were developed. However, it is important to note that there are similarities in the models. Both support the transmission and application of information.

THE OSI NETWORK MODEL

The OSI model consists of seven hierarchical layers. Each layer performs a related subset of the functions required to communicate with another system. Each layer relies on the next lower layer to perform more primitive functions and to conceal the details of those functions. It provides services to the next higher layer. The layers are defined in a manner such that changes in one layer do not require changes in the other layers. With partitioning of the communication functions into layers, the complexity of the protocol is manageable.

THE OSI LAYERS

The following is a description of the layered architecture, starting from the bottom of the stack.

- *Physical.* This layer is concerned with transmission of an unstructured bit stream over the physical link. It invokes such parameters as signal voltage swing and bit duration. It deals with the mechanical, electrical, and procedural characteristics to establish, maintain, and deactivate the physical link.
- *Data Link.* This layer provides for the reliable transfer of data across the physical link. It sends blocks of data (frames) with the necessary synchronization, error control, and flow control.
- *Network.* This layer provides upper layers with independence from the data transmission and switching technologies used to connect systems. It is responsible for establishing, maintaining, and terminating connections.

- *Transport*. This layer provides reliable, transparent transfer of data between end points. It provides end-to-end error recovery and flow control.
- *Session*. This layer provides the control structure for communication between applications. It establishes, manages, and terminates connections (sessions) between cooperating applications.
- *Presentation*. This layer performs generally useful transformations on data to provide a standardized application interface and common communications services. It provides services such as encryption, text compression, and reformatting.
- *Application*. This layer provides services to the users of the OSI environment. These services are for FTP, the transaction server, network management, end-user, and more.

Figure 1.19 illustrates the OSI model. Notice that the model pictures a stack of layers. The foundation layer is the physical layer. Every other layer is built on top of each preceding layer. You can see how these layers are interdependent.

The SS7 protocol is similar to the OSI model. It supports four layers, while the OSI model supports seven. The functions of the SS7 layers are similar to the those of the OSI model.

The OSI model is a broad view of data transmission and applications. The SS7 model has been specifically designed to meet the evolving needs of the telecommunications industry.

THE SS7 MODEL AND THE SS7 LAYERS

The following is a description of the four layers of the SS7 model:

- *Physical*. The physical layer in this model is nearly the same as in the OSI model. Unlike the OSI model, the SS7 model allows specific network interfaces to be identified. Today, the most often used interface is the DS-0 level network interface. This represents a data rate of 56 or 64 kbps.

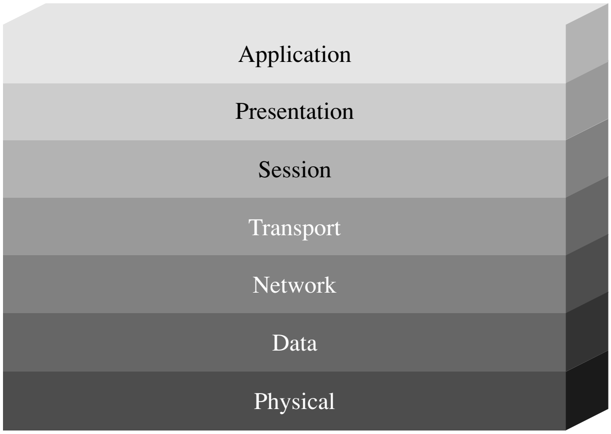


FIGURE 1.19 The OSI Model

Therefore, today all SS7 links operate at the DS-0 level. Industry practices in North America, as specified by Bellcore, support link rates at the DS-0 level. The ANSI SS7 standard does not specify a specific interface. Current industry work within North America is seeking to use ATM for the transport of SS7 messages. ATM will be implemented to support broadband networks.

- *Data Link.* This layer provides the SS7 protocol stack with error detection and correction and enables the sequential delivery of SS7 messages. This layer is similar to its counterpart in the OSI model. The data-link layer addresses only the transmission of data from one network node to another network node. This layer is not responsible for routing. As the SS7 message is transmitted from one node to another node, each node performs digit screening (review). The information gained from the dialed digits is used to determine the next node for the SS7 message.
- *Network.* This layer provides for message review, routing, and distribution. The routing function enables the network to determine the address to which the message must be routed. The message review capability enables the network to determine to whom the message is addressed. The message distribution enables the network to identify to which user part the message is addressed. Within this layer there are three network

management functions: link management, route management, and traffic management. These capabilities are an integral part of the layer and enable the broader functions to work.

– User Parts and Application Parts. This layer consists of several different components. The primary components are:
  – ISDN User Part (ISUP)
  – Transaction Capabilities Application Part (TCAP)
  – Operations, Maintenance and Administration Part (OMAP)
  – Mobile Application Part (MAP)
  – Application Service Part (ASP), which includes MAP
  – Signaling Connection Control Part (SCCP)

Figure 1.20 illustrates the SS7 model.

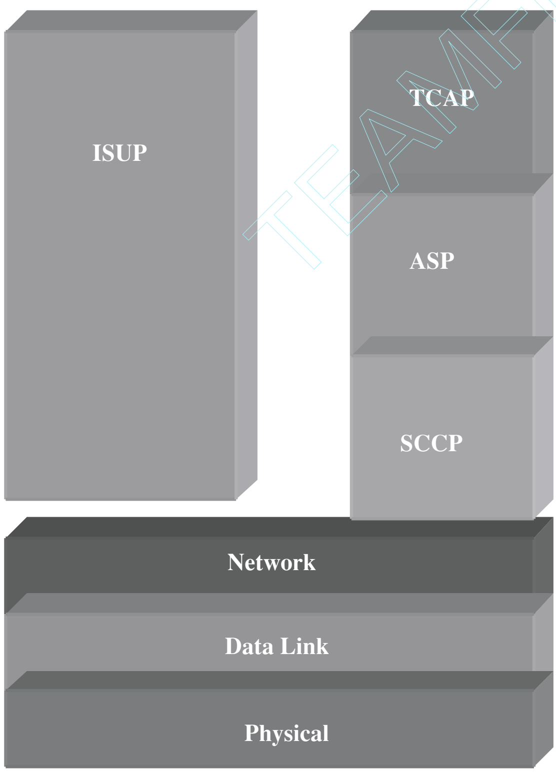


FIGURE 1.20 SS7 Model

Layers 1, 2, and 3 correspond to Layers 1, 2, and part of Layer 3 in the OSI model. Layer 4 corresponds to Layers 3 through 7 of the OSI model. See Figure 1.21.

Figure 1.22 is an example of how an SS7 call is processed.

Network signaling protocols are designed to perform specific functions. There are no network signaling protocols in existence capable of being all things to all services. The protocols I have described can provide any variety of services, even limited video applications. However, when one queries the marketplace, one will hear that the view of multimedia is:

- Streaming video
- Streaming audio
- Interactive Internet-based games
- Real-time video communication between multiple parties

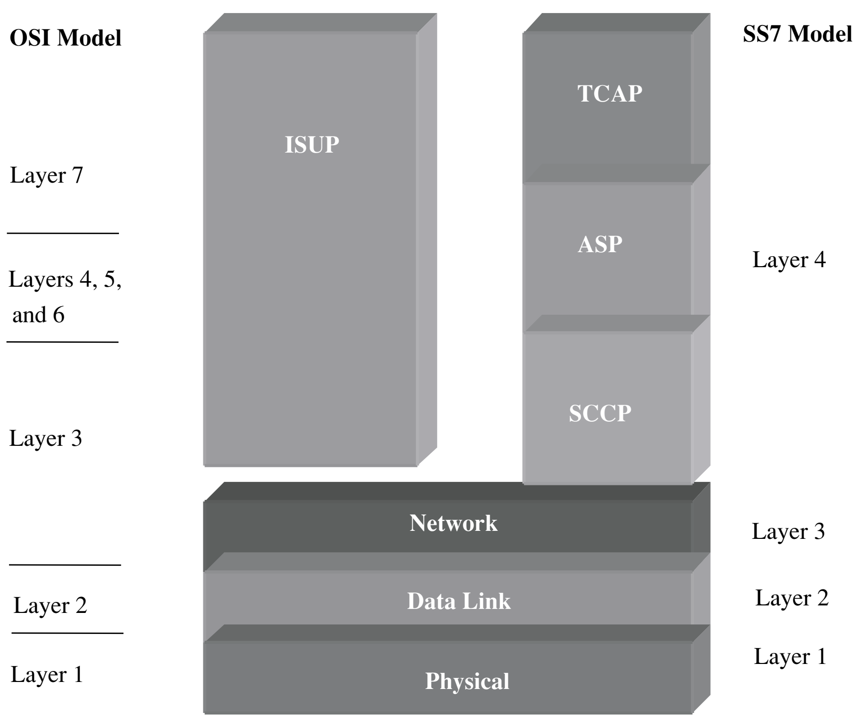
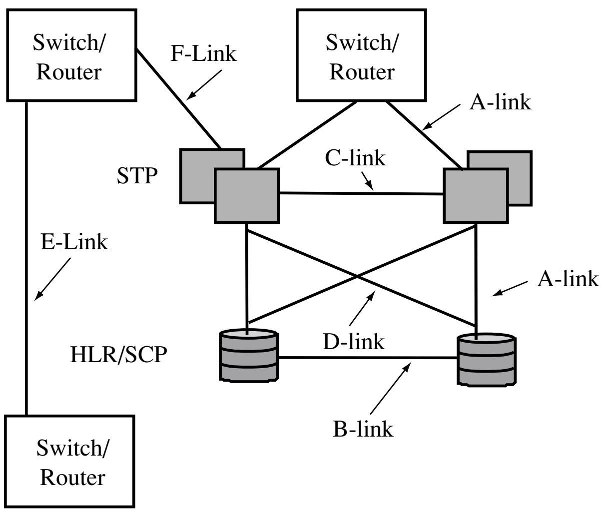


FIGURE 1.21 SS7 Model versus OSI Model



- User enters digits of called telephone number.
- Switch queries database, known as the HLR (wireless) or SCP (wireline), to determine how call should be processed and to request information regarding any special billing treatment.
- The SCP/HLR sends call setup directions to the STP.
- The STP then queries network for available transmission facility connection.
- Call is set up.

FIGURE 1.22 SS7 Call Processing

TRANSITIONING EXISTING NETWORK TECHNOLOGY: ISSUES

A flurry of video and audio formats have entered the marketplace. Network owners are working to find and install the most robust network technologies to meet the demand (anticipated or perceived) of the marketplace. The economics of changing an entire network are staggering but these changes must be done in order to support the new broadband multimedia services.

Broadband technology should be viewed in terms of physical capacities and services requirements. The physical transmission media must be capable of supporting the transmission rates. The signaling used on the transmission media must be capable of supporting the various multimedia application characteristics. In other words, you must know the service to be provided to the user, the technical characteristics of the service, and the user's requirements for the service before you can adequately design and engineer the appropriate network. This boils down to the following:

- Know customer requirements
- Know customer expectations
- Set customer expectations
- Meet customer needs

SUMMARY

This chapter established a foundation of knowledge for understanding broadband. The following chapters will delve deeper into the technologies. The challenges for the service provider and the business community in the realm of broadband have been:

- Finding the "killer application" that will cause the customer base to spend its money on buying the service
- Finding the appropriate broadband technologies
- Transitioning existing network technologies to newer broadband network technologies
- Building the business case

This may seem obvious, but, when you are seeking a financial opportunity you can be blinded by technomarketing hype. There will be more on this later in the book. Multimedia transmits presents information in several simultaneous media forms and modes such as video, graphics, sound, and music.

The following chapters will focus on the popular broadband technologies designed to exploit the capabilities of fiber optics, metal, and wireless.

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CHAPTER TWO

TRANSMISSION CONCEPTS

This chapter focuses on fiber optic technology and the role it plays in supporting broadband technologies. Transmission systems have four components:

- A source of energy—voice, data, radio frequency energy, etc.
- A medium to carry this energy—metal, fiber optics, air
- Transmission electronics
- Receiver electronics

Until the late 1990s, the field of transmission systems was not exactly a glamorous telecommunications career builder. However, the birth of the Internet has caused a growth spurt in this field, especially in the area of local loop enhancement. More than any other market segment, the Internet has caused the telecommunications business and the investment community to shift money toward transmission systems development; people want faster access and interaction with the Internet. The telecommunications carriers had moved into fiber optics prior to the Internet, primarily due to conduit space restrictions and maintenance requirements. (There will be more discussion of applications later in this book.) Figure 2.1 illustrates the basic components of a transmission facility. The remainder of this chapter will focus on transmission basics.

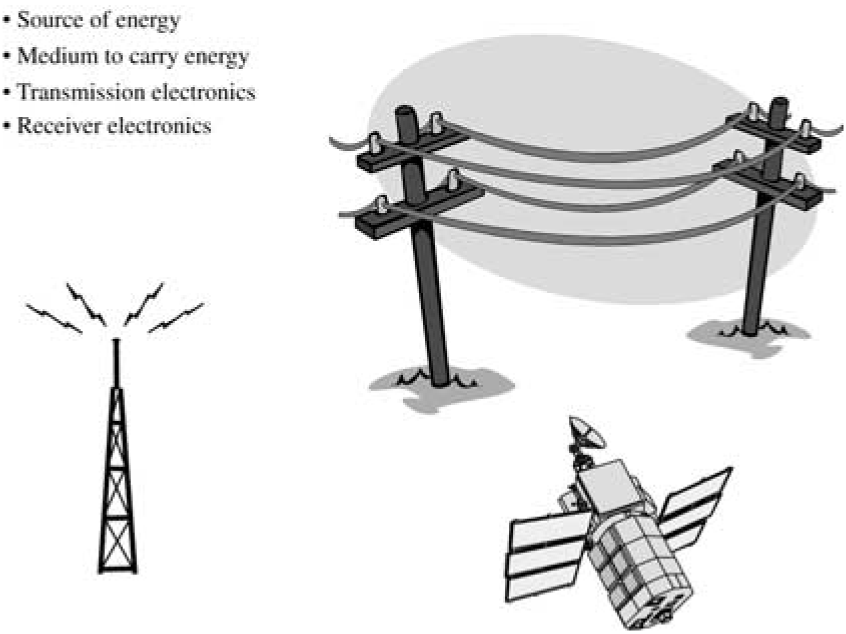


FIGURE 2.1 Transmission System Components

Voice is the basic information component upon which all transmission concepts were built. An old Bell System (pre-divestiture AT&T; 1984 and earlier) axiom was that the optimal balance between economics and quality of transmission occurs when the telephone speech signal is band-limited to the range from about 300–3,300 Hz. Furthermore, it is my contention that voice is the mass-market service all carriers need to offer. Therefore, we will be using voice as a starting point for this chapter. There are five basic impairments to voice transmissions over any medium. These are:

- Attenuation distortion
- Phase distortion
- Noise
- Echo
- Singing

The following subsections will describe these impairments.

BASIC IMPAIRMENTS TO VOICE TRANSMISSIONS

Understanding what is considered an impairment to the "basic" telecommunications service is an excellent way of understanding how to judge other transmissions media.

ATTENUATION DISTORTION

Attenuation distortion is a frequency distortion of voice. A person's voice tends to vary by amplitude (loudness) and frequency (pitch) during speech. An example of an attenuation distortion would be when the frequency of a person's voice varies differently for the same amplitude and frequency combinations. The sound you hear could only be described as disturbing. Note that attenuation is the decrease in power of a signal; for example light, radio waves, or even voice.

The attenuation distortion of a voice can be stopped if all frequencies of the voice conversation are attenuated (decreased in power or amplitude) in the exact same manner. You may hear this over a wireline telephone or wireless handset. Some people may have noticed how different their friends sound over either of these telecommunications devices. The differences have a great deal to do with how the telecommunications provider's system is attenuating the voice. In speech, a conversation is a rich mixture of overlapping frequencies; a person's voice ID print is unique because of this richness in tones and sounds. The person speaking through a telecommunication device can be understood, but sounds different from the sound produced by speaking in person (live and in front of the listening party). However, the differences become subjectively disturbing when the attenuation varies.

To minimize the variances from attenuation distortion, filters are designed to operate with specific reference points. Around these reference points the human voice is allowed to vary within certain limits. In Europe, 800 Hz is used as a reference point for frequency modulation control. In North America, 1010 Hz is the reference point. Frequencies closer to the reference suffer less loss or gain than those frequencies further away. See Figure 2.2 for an example of attenuation distortion.

PHASE DISTORTION

Signals take a finite and measurable amount of time to travel from point to point. The signal will travel at different speeds in different media. For instance, a signal traveling in a vacuum will travel faster than a signal traveling through glass, metal, or the atmosphere. For each type of medium and subcategory of media, an electromagnetic signal will travel at different speeds. Figure 2.3 illustrates this concept.

Another variable in signal speed is frequency. Voice is transmitted as an electromagnetic signal. Frequency is a component that cannot be ignored. Remember that a transmission facility, made of any kind of material, is a pipe or roadway for information. Any roadway has an absolute limit on the number of vehicles it can handle at any given time, given specific safety parameters, vehicle size, and vehicle speed. The signal has its

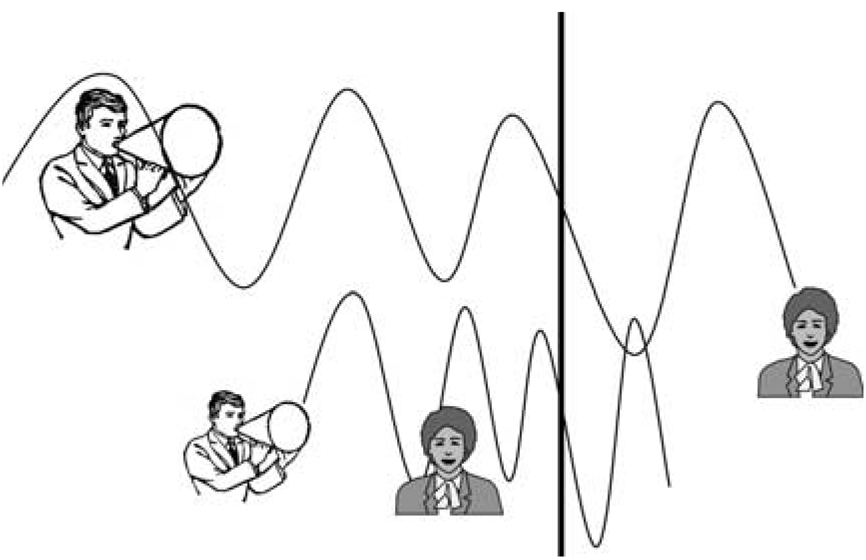


FIGURE 2.2 Attenuation Distortion

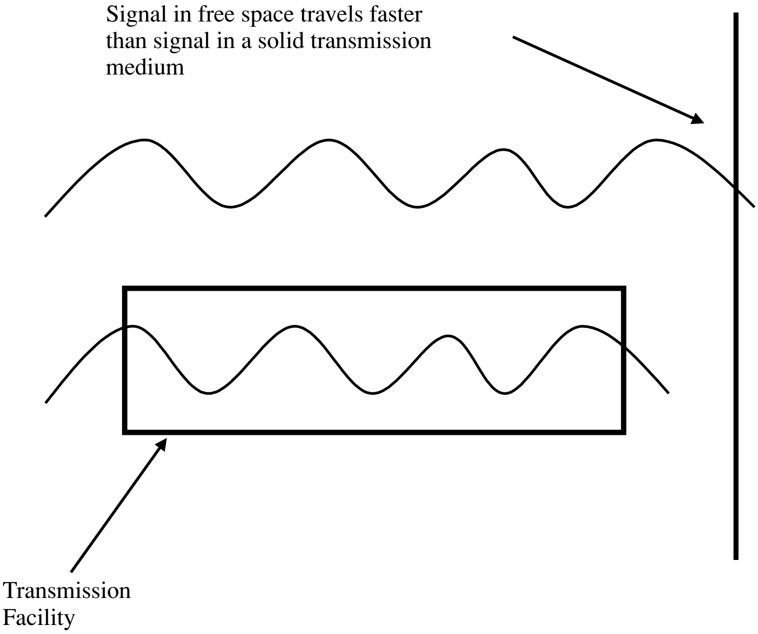


FIGURE 2.3 Time and Signal Speed: A Function of Media Type

own characteristics, and these characteristics must be taken into account.

If we use the human voice as a baseline, we find that as voice travels through a medium it encounters a variety of delays. These delays will affect the various frequencies of conversation. These frequencies will have different transit (propagation) times for each different set of frequencies. Consider a voice as a set of ocean wave fronts, each affected differently by the ocean floor. The wave fronts of human voice can arrive out of the sequence in which they were generated. These shifts are called phase shifts. These phase shifts could occur at random, affecting the quality of the human voice being transmitted. The voice conversation would sound "garbled" to a listener, for lack of any better way of describing the distortion.

To minimize phase distortion, telecommunications carriers work to minimize the absolute delay a signal encounters in the telecommunications circuit. In other words, the telecommunications carriers works to minimize the macro delays a signal could encounter. Absolute delay is the delay a signal experiences when it passes through a network, from end to end. The steps a carrier takes to minimize absolute delay include:

- Reducing inductive effects in the transmission facility used by the local loop.
- Reducing inductive effects caused by the transmission of an electromagnetic signal in a long distance facility.
- Minimizing the use of repeaters in a transmission facility. Note that a rule of thumb used by many transmission engineers is the fewer the nodes to transit, the fewer delays caused by a piece of equipment.
- Engineering the facility to perform optimally around a certain base frequency. For instance, absolute delay for voice is minimal around the 1700 Hz frequency set. Human voice operates in the 300–3,300 Hz band.

NOISE

Noise is defined as any unwanted or undesirable signals on a transmission facility. Another way of looking at noise is as a signal that causes degradation or distortion of the original signal. There are four types of noise:

- Thermal
- Intermodulation
- Crosstalk
- Impulse

Figure 2.4 illustrates these four types of noise.

THERMAL NOISE. Thermal noise occurs in all types of transmission media. "Thermal" refers to heat. The random electron motion in transmission media generates heat. In fact, heat is generated in all kinds of telecommunications equipment.

The noise generated by thermal activity is the electromagnetic interference caused by this random motion of electrons.

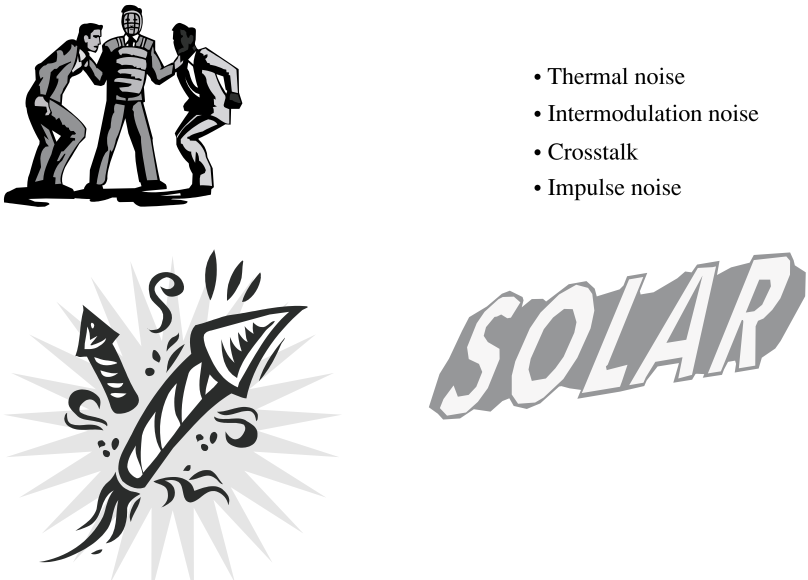


FIGURE 2.4 Noise

Thermal noise is what mandates the establishment of maximum operating temperatures for equipment. Thermal noise is referenced to the temperature of absolute zero, which is approximately 459.5 degrees below zero on the Fahrenheit scale. Thermal noise also establishes the lower limit of sensitivity for radio receiving equipment.

Figure 2.5 illustrates thermal noise.

INTERMODULATION NOISE. Intermodulation is the production of frequencies corresponding to the summation of the multiple frequencies generated by nonlinear transmission systems. These multiple frequency sets include the multiple frequencies caused by the distortion of a nonlinear system. Intermodulation noise is the result of these frequency sets. The multiple frequency sets are also known as harmonics. Harmonics can be likened to distorted images of the original signal.

Intermodulation noise can be caused by:

- Improper level setting of a device. This may result in setting the input levels higher than the operating electronics can

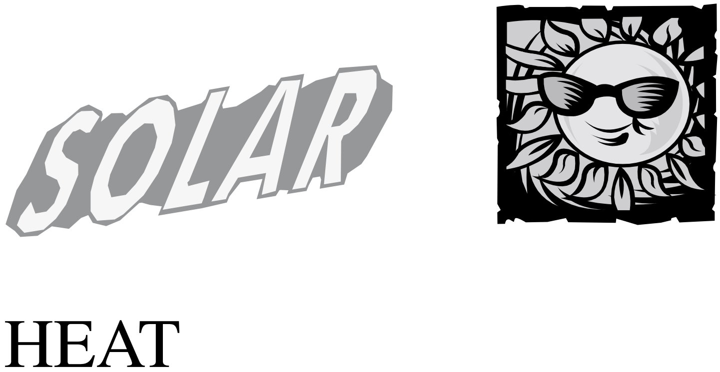


FIGURE 2.5 Thermal Noise

handle, with the result being the input device may be forced into overdriving its own capabilities.

- Device malfunction.
- Non-linear Envelope Delay Distortion (EDD). EDD is the distortion caused by multiple signals that traverse a transmission facility. The distortion is caused by the random signal wave shifts caused by the arrival of the signals at their destination at different and varying times.

Now imagine a telecommunications network carrying multiple signals (conversations) when intermodulation occurs. The resulting intermodulation noise can become so overwhelming that it sounds like white noise. Figure 2.6 is a representation of intermodulation noise.

CROSSTALK. Crosstalk occurs when signal paths are crossed and each party can hear itself while hearing, sometimes only partially, other extraneous parties. Crosstalk is usually referred to as "crossed wires." Crosstalk can be caused by:

- Electrical coupling between transmission media; i.e., crossed wires
- Poor frequency response control

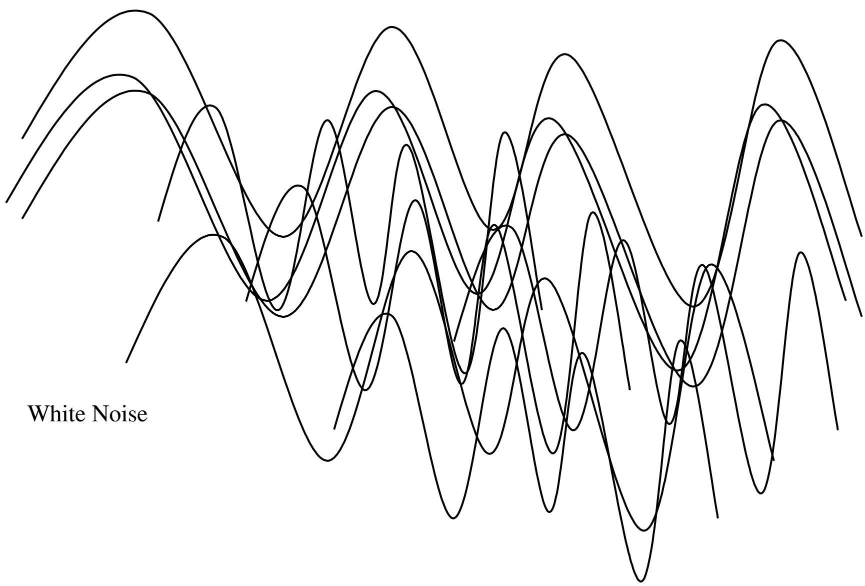


FIGURE 2.6 Intermodulation Noise

The following are types of crosstalk:

- *Intelligible*. Intelligible crosstalk is where at least four words from the extraneous conversation are intelligible to the listener in an 8-second period.
- *Unintel*ligible. Unintelligible crosstalk is essentially everything and anything else that is heard during a conversation.

To most people, intelligible crosstalk is more disturbing to listen to than unintelligible crosstalk. In the intelligible crosstalk scenario a listener will hear enough conversation to realize that the extraneous party probably hears almost as much from the listener. It gives all parties the "heebie geebies" about loss of privacy. The fact is, in intelligible crosstalk scenarios, parties have been known to comment about what they hear to one another, even going as far as telling the extraneous party to "get off the line."

Unintelligible crosstalk scenarios are simply distracting noises that sometimes sound like the human voice. Figure 2.7 is an illustration of crosstalk.

FIGURE 2.7 Crosstalk

IMPULSE NOISE. Impulse noise is spurious, noncontinuous, bursty, irregular, electromagnetic spikes. These spikes are short-term bursts. The spikes may occur due to irregular system performance, faulty grounding, external power grid troubles, faulty relays in old wireline electromechanical switches, and even lightning strikes. It sounds like a "popping" or "clicking" noise. Impulse noise can seriously degrade system performance and the integrity of data. Figure 2.8 is a representation of impulse noise.

ECHO

Echo occurs when a speaking party hears his or her own voice as a reflection. Echoes are created due to some kind of irregularity in the transmission path. However, echo must be sufficiently delayed to be heard or noticed. Transmission signals travel at a defined speed through a transmission path, therefore the cause of the echo must be distant enough on the transmission path to be time-delayed in order to be heard. Echo is typically not a problem on short transmission paths.

FIGURE 2.8 Impulse Noise

Echo can degrade low-speed modem performance over the twisted-wire pair from a residential phone. From a voice perspective, echo is disturbing to listen to; it is a major annoyance. Tolerance for echo is subjectively measured. Echo becomes intolerable when:

- It is so loud it hurts.
- The length of delay for each echo is so long it extends a conversation beyond all tolerance.

Figure 2.9 is an illustration of echo.

SINGING

Singing is voice gone out of control. Technically, singing is the result of sustained oscillations due to feedback in the amplifiers. Resonance is another way of describing this effect. Resonance occurs under specific electrical circuit conditions,

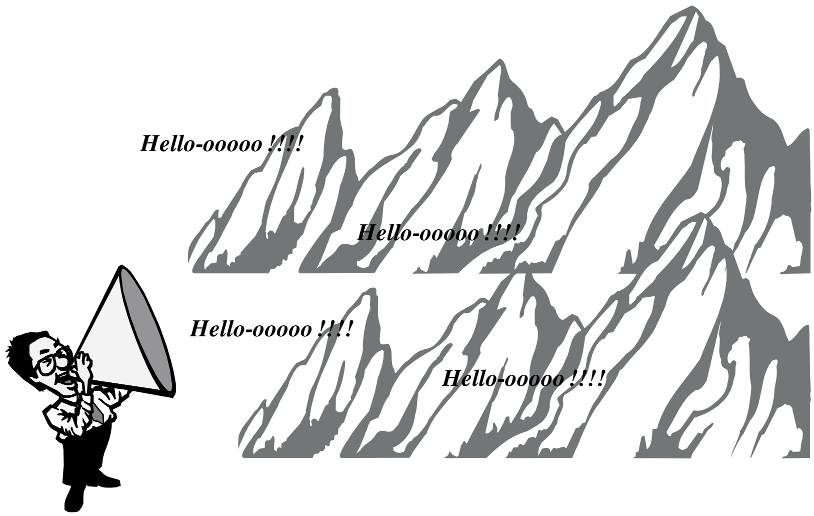


FIGURE 2.9 Echo

when inductance equals capacitance in a circuit. The singing frequency is equal to the original signal frequency. The singing signal can continue its oscillations even after the original signal has shut down. Overloads in circuitry can occur due to singing. Singing sounds like a person shouting in a barrel or big steel drum; the person is shouting at such a pitch he sounds as if he is about to "screech." Figure 2.10 is a representation of singing.

An example of resonance is a famous bridge collapse in the 1940s. The Tacoma Narrows Bridge was struck by a wind blowing at a frequency that equaled the resonant frequency of the materials in the bridge. The frequencies built upon one another resulting in the bridge's complete collapse due to harmonic resonance in high wind.

DIGITAL AND ANALOG: WHAT ARE THEY?

As I noted in Chapter 1, analog is defined as an electromagnetic or audio signal that can assume any value. Digital can only assume discrete values within the signal. A voice, sound,

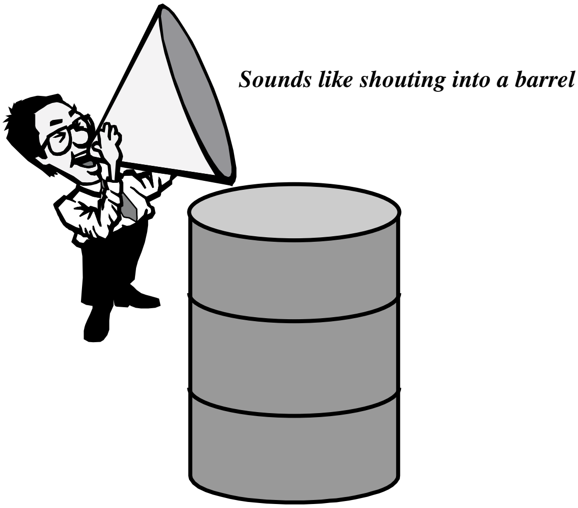


FIGURE 2.10 Singing

or electromagnetic signal can be pictorially drawn as a waveform. Figure 2.11 is a depiction of an analog waveform. Figure 2.12 is a rendering of a digital waveform.

Analog waveforms can assume any shape. The shape can be irregular or smooth and symmetric on both sides of the axes. Examples of an analog waveform are sawtooth, sine wave, and

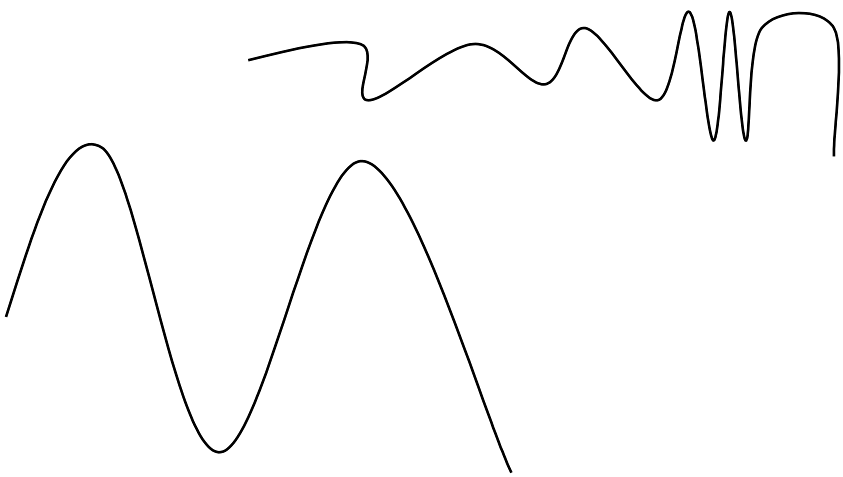


FIGURE 2.11 Analog Waveform

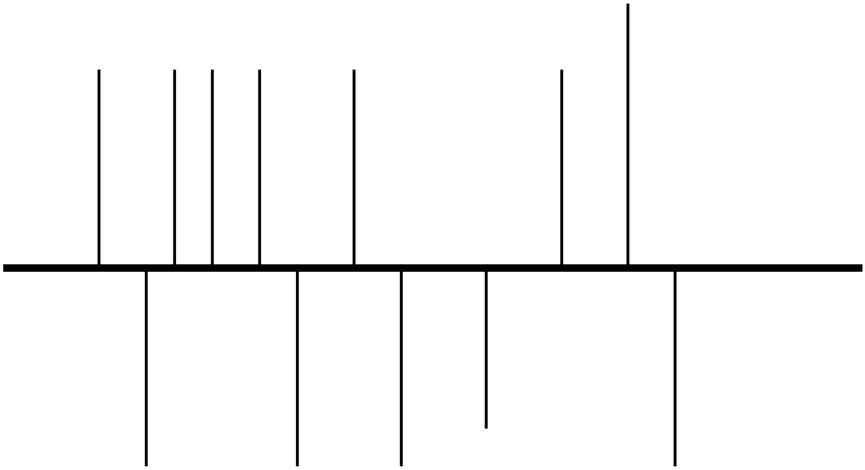


FIGURE 2.12 Digital Waveform

square wave. The digital waveform equivalent of the pictured analog waveform (Figure 2.11) can be seen in Figure 2.12. The reader will note that the digital sample is nothing more than a representation of the analog waveform and is not an exact of the analog waveform.

The IEEE defines analog and digital signals as follows:

> "An analog signal implies continuity, as contrasted to a digital signal that is concerned with discrete states. Often the means of carrying information is the distinguishing feature between analog and digital. The information content of an analog signal is conveyed by the value or magnitude of some characteristics of the signal such as phase, amplitude, frequency of a voltage, the amplitude or duration of a pulse, and so on. To extract the information, it is necessary to compare the value or magnitude of the signal to a standard. The information content of a digital signal is concerned with discrete states of the signal, such as the presence or absence of a voltage, a contact in the open or closed position.... The digital signal is given meaning by assigning numerical values or other information to the various possible combinations of the discrete states of the signal."

MULTIPLEXING

Multiplexing is a process of simultaneously transmitting more than one signal over a single physical transmission path. Multiplexing a signal can be performed in two ways:

- Frequency Division Multiplexing (FDM)
- Time Division Multiplexing (TDM)

In the 1970s, the T-1 facility became very popular with North American local and long distance telephone companies. It was an efficient means of transporting multiple conversations across a distance. FDM was the popular way of creating the 24 channels in a T-1 facility. FDM did not digitize the signal. It is a method of allotting a band of frequencies in a wideband transmission medium. An FDM multiplexer accepts voice inputs in the 0–4,000 Hz frequency range. Each conversation is assigned a specific channel. For instance, Channel 1 accepts the voice input, unchanged, in the 0–4,000 Hz range. Channel 2 translates or converts the 0–4,000 Hz voice input into a frequency band of 4,000–8,000 Hz band. Channel 3 operates in the 8,000–12,000 Hz range, and so on and so on. If we add up the 24 channels, we produce a single combined signal of 96,000 Hz. Note that a copper path twisted-pair, can easily handle 100,000 Hz of bandwidth. See Figure 2.13 for an illustration of FDM.

FDM was used for N or L carriers. N carrier was for local-loop applications and was transmitted over repeated copper facilities. L carrier was for long haul applications and was transmitted over coaxial facilities.

The concept of multiplexing is very old. FDM has been in use since the days of the vacuum tube. Multiplexing by frequency enabled service providers (carriers) to transport analog signals for years. However, as the years went by and the number of long distance calls increased, the wireline telephone companies discovered that noise became a major problem.

As signals traversed the long distance transmission facilities, these signals needed to be amplified. Transmission signals

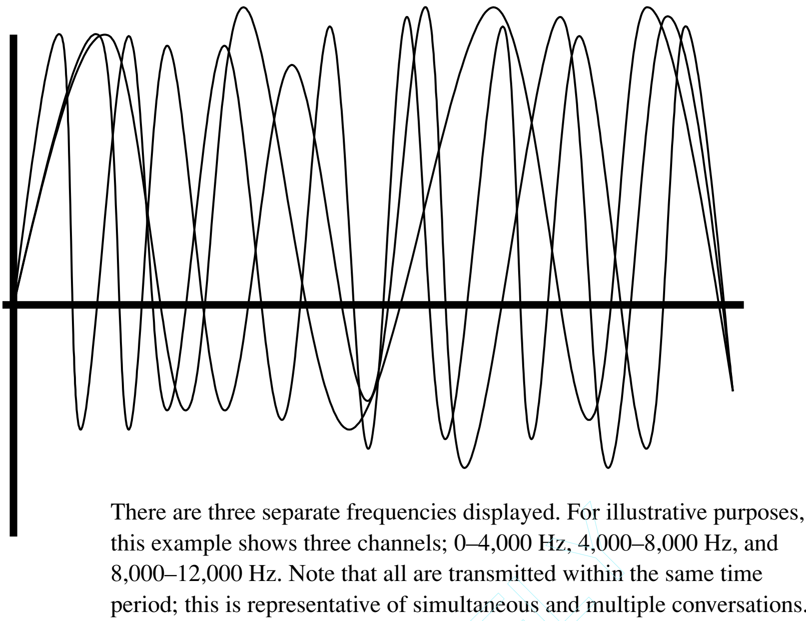


FIGURE 2.13 FDM (Frequency Division Multiplexing)

from the user fade over distance. The voice signal from the user was amplified, but amplifiers cannnot separate out the voice from noise. Therefore, noise was amplified along with the voice. As recently as the mid-1960s, noise over a long distance connection was a problem. It was not until the mass introduction of digital transmission that the noise problem was finally brought under control. Figure 2.14 is a representation of the analog signal noise issue.

Time Division Multiplexing (TDM) is another way of creating additional channels on a transmission facility. TDM was the technique used by the wireline carriers to first digitize voice, thereby eliminating the analog noise–related issues.

Digital transmission became important because long-haul communications went from being infrequently used to an everyday habit. During the last 20 years of the twentieth century, long distance communications increased as society became more mobile and families began to move to find new lives and work. This meant families began to spread across the nation. This also meant that calling habits changed from being

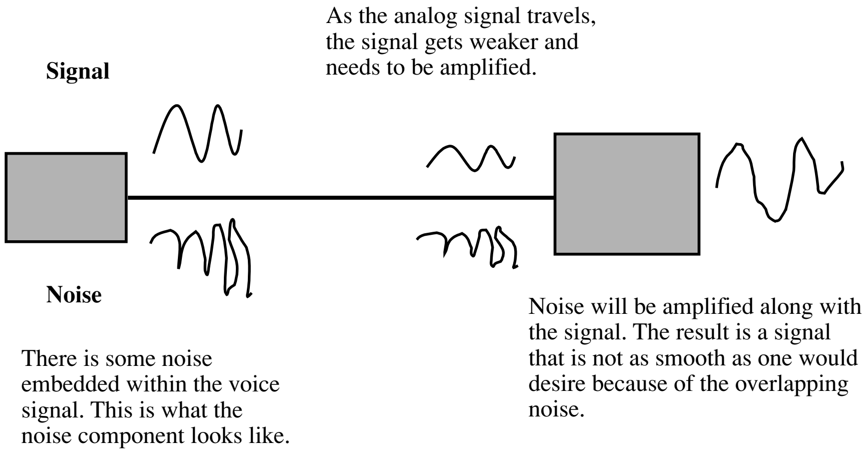


FIGURE 2.14 Analog Noise Amplification

primarily local to primarily long distance. Digital transmission became a necessity to ensure the quality of the voice transmissions and to improve the efficiency of the network. While FDM created additional channels for analog voice transmission over network facilities, a method had to be created that digitized the information. That method was TDM. The advantages of digital transmission are:

- Signals can be regenerated, rather than simply amplifying the overall signal and any associated noise.
- Noise is not amplified.
- The digital signal can be more easily encoded than if it were an analog signal.
- Digital signals lend themselves to digital technology.

Figure 2.15 is an illustration of the digital waveform.

In general, one can describe an analog waveform as comprised of signals continuously varying in amplitude. The digital waveform is comprised of a limited number of discrete amplitude values. TDM is a multiplexing method that divides the transmission facility bandwidth into time slots. Each voice conversation is assigned a unique time slot in a continuous

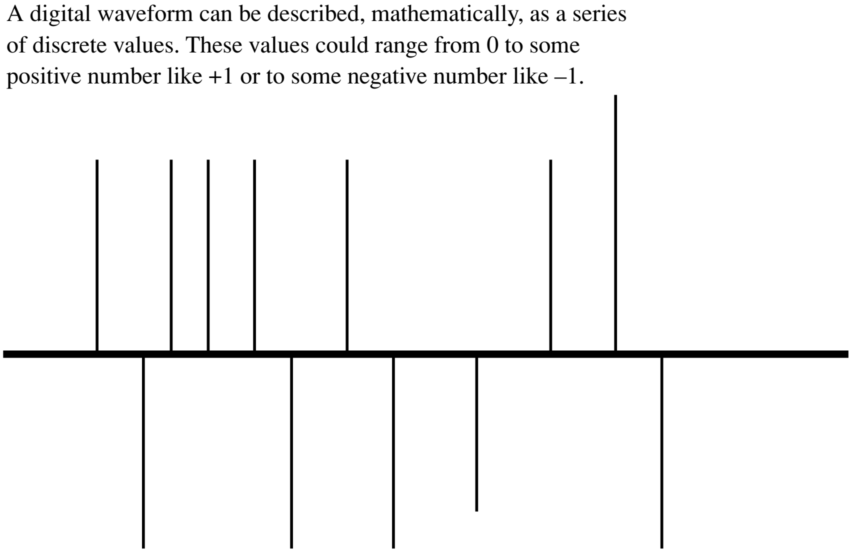


FIGURE 2.15 Digital Waveform

rotation. The devices, known as multiplexers, enable the 24 voice channels to share the same facility. See Figure 2.16 for an illustration of TDM.

DIGITIZING THE ANALOG SIGNAL: PULSE CODE MODULATION

The worldwide standard for digitizing an analog waveform is a modulation technique called Pulse Code Modulation (PCM). PCM is a conversion method that can be broken down into two steps: sampling and coding. The sampling method is known as Pulse Amplitude Modulation. The coding schema is actually comprised of two steps: quantization and digital encoding.

PULSE AMPLITUDE MODULATION (PAM)

To explain PAM, let's go through an example. An analog signal is being transmitted. The signal is a voice conversation, operating in the 0–4,000 Hz range. The signal is sampled at a rate of 8,000 times per second. In other words, 8,000 dis-

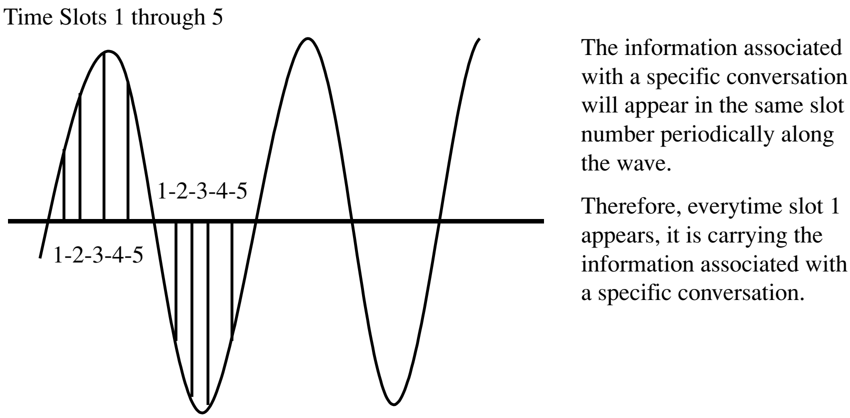


FIGURE 2.16 TDM (Time Division Multiplex)

crete points within the analog waveform are identified. This equates to marking a point on the waveform every 125 microseconds (125×10^{-6} seconds). This can be likened to a child's drawing of connecting the dots. If one were to take a child's connect-the-dots drawing, one would be able to discern the picture or character described by the dots without actually having to connect the dots. See Figure 2.17 for an example of a child's connect-the-dots drawing. In this case, we are connecting the dots of an analog waveform. This method of sampling is consistent with the Nyquist Sampling Theorem, which states that:

> If a band-limited analog signal is sampled at regular time intervals and at a rate equal to or higher than twice the signal frequency, then the sample contains all of the information of the original signal. The original signal can be reconstructed from the sampled signal using the appropriate filters.

Figure 2.18 is a representation of an analog waveform that has been sampled.

For those who have never seen a child's connect-the-dots drawing, another way of looking at sampling is if you imagine a board fence, the kind you would find in a backyard. If you remove 70 percent of the boards, you could still discern the

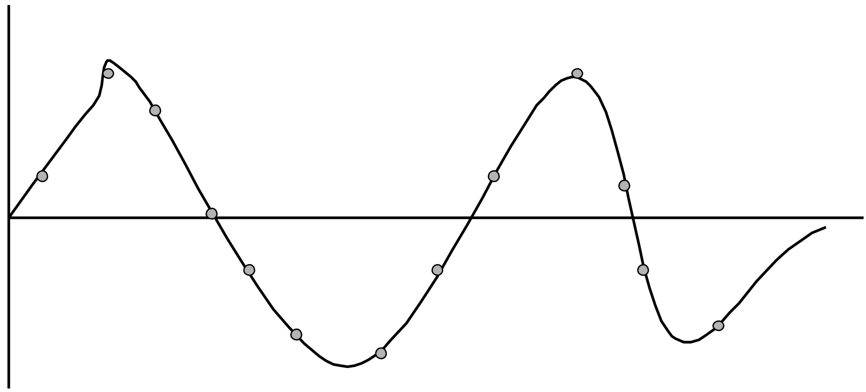


FIGURE 2.17 Sampling Resembles a Child's Connect-the-dots Drawing

shape or line of the fence top. Figure 2.19 is another example of sampling.

Note that if sampling were not fast enough for the frequency being sampled, the result would be a set of discrete points that might appear to represent a single analog waveform when in fact there are two waveforms. This scenario is known as aliasing. The result of aliasing is unintelligible sound. Voice transmission systems are designed with low-pass filters that block out frequencies above 4,000 Hz. Figure 2.20 illustrates aliasing.

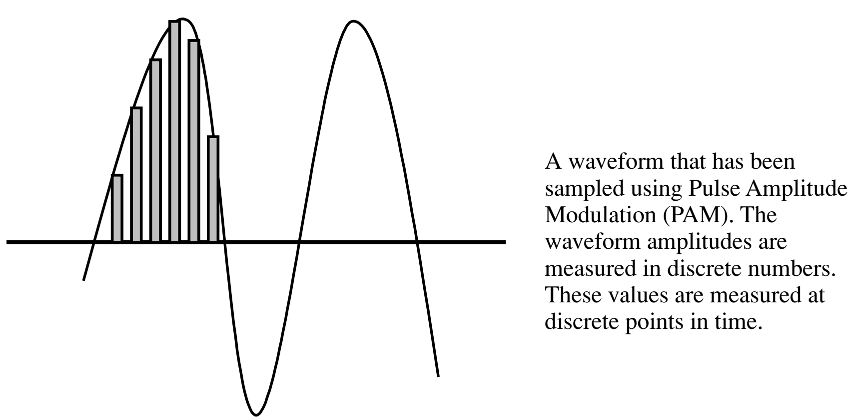


FIGURE 2.18 Sampled Waveform: PAM

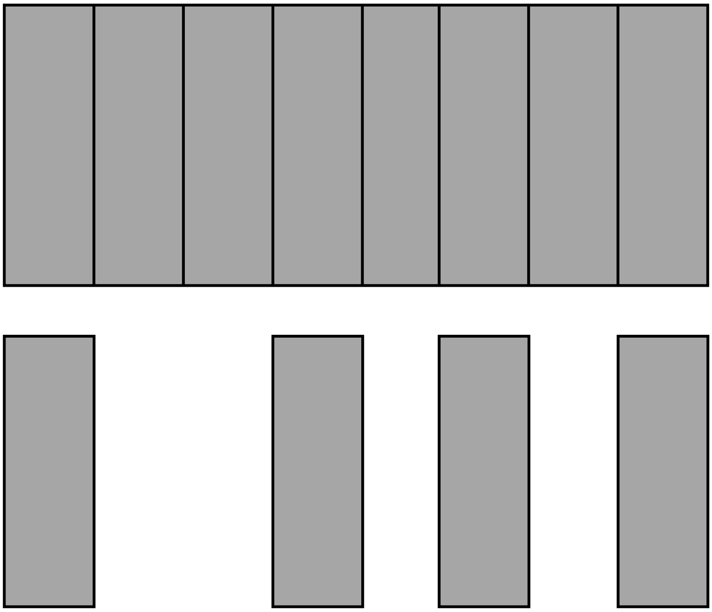


FIGURE 2.19 Another Example of Sampling

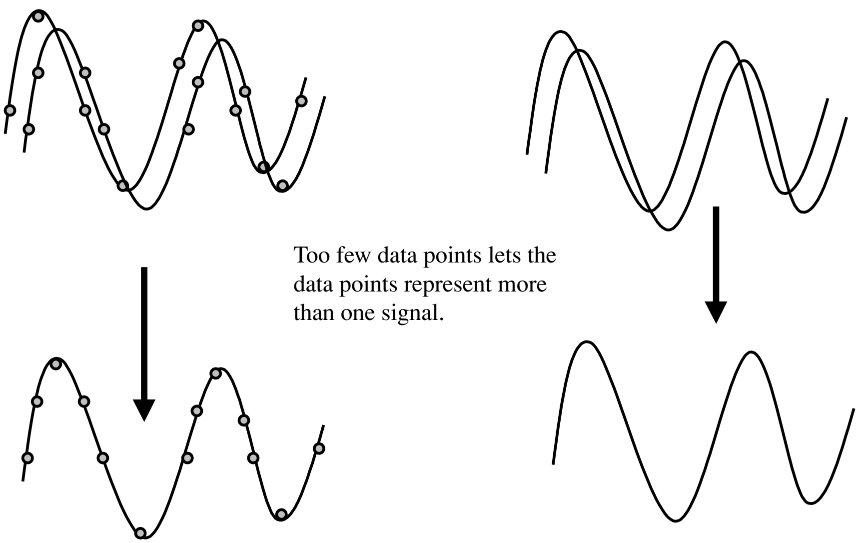


FIGURE 2.20 Aliasing

CODING

As noted, the digital encoding step is comprised of two steps: quantization and digital encoding.

QUANTIZATION. An analog waveform sampled by the PAM technique is comprised of some number of discrete sampled points. The waveform itself has set upper and lower voltage amplitude boundaries. Assume that the PAM waveform has an upper boundary of +1 volt and a lower boundary of −1 volt. Using the PAM sampling methodology just described, we find that the samples can assume an enormous number of values. Essentially, we find that the number of sample values is infinite. For example, one of the sample values could be +0.001234578, or −0.001234578, or +0.001234579. Obviously, reasonable criteria must be established, otherwise a coding schema to support an infinite number of values would have to be designed. In other words, a practical limit for deployment purposes must be established. Figure 2.21 illustrates quantization.

One way of establishing a practical limit to the number of sample values is by setting a fixed number. For example, you could say that a limit of ten discrete values can be established. This would mean that for an analog waveform varying between +1 and −1 volts a sample would be taken at every 0.2-volt increment.

Note that the binary numbering domain is used in telecom computing. This means that if the encoding schema supported a 2-bit binary code, only four values could be set as discrete sample points. If a 3-bit binary code were established, then eight different values could be supported. If a 4-bit binary code were used, then sixteen different values could be supported—the number of discrete sample values would be equal to 2^n. Figure 2.22 illustrates the concept of binary numbering. The standard for quantization is 28, or 256 different binary combinations.

Figure 2.23 illustrates an example of a PAM waveform that has a quantization scheme applied.

The resulting sampled waveform using quantization is not an exact match for the original analog waveform. In fact, since

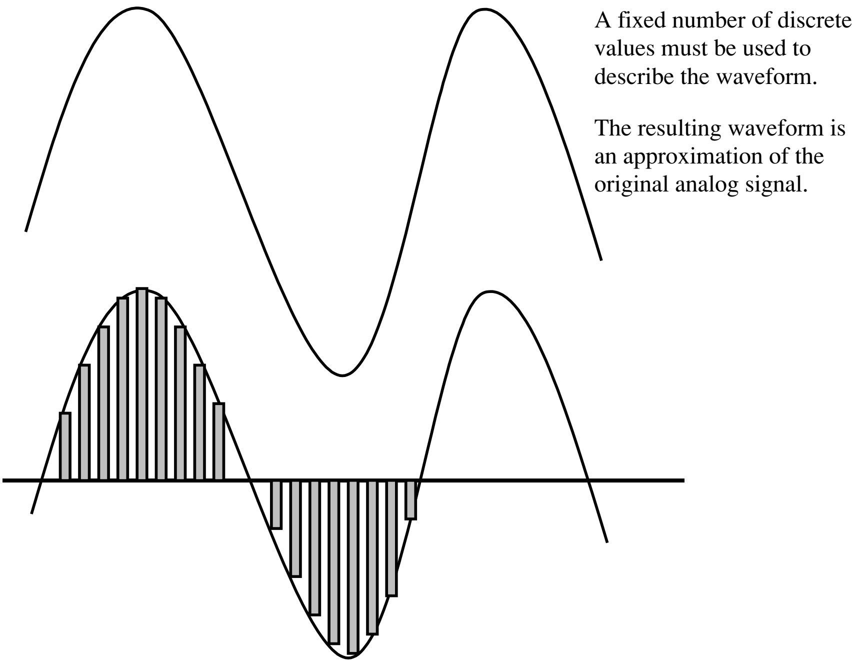


FIGURE 2.21 Quantization

Quantum Step	Binary Code
0	00000000
1	00000001
2	00000010
3	00000011
4	00000100
5	00000101
6	00000110

8-bit code representing six quantum values

FIGURE 2.22 Binary Combinations

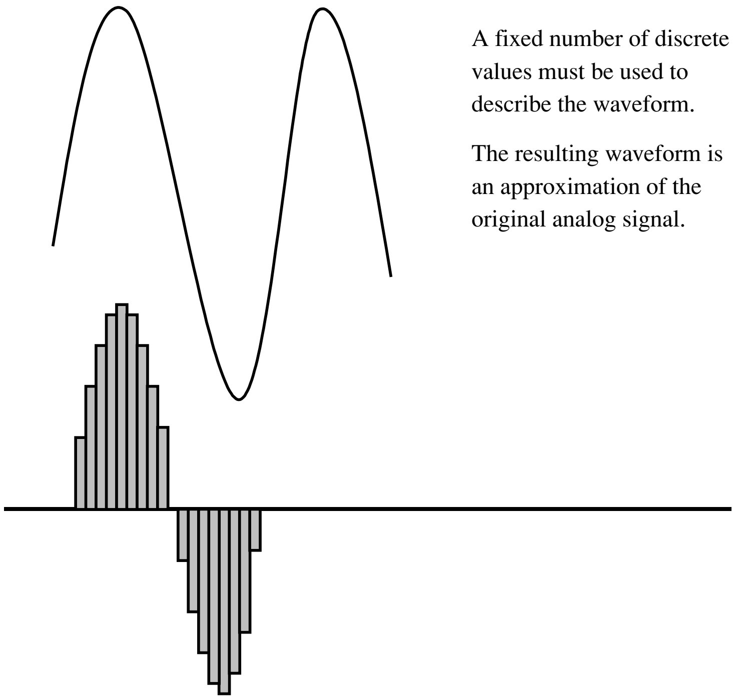


FIGURE 2.23 Quantization and a PAM Waveform

the quantized steps are whole integrals, a large number of analog waveform values are not duplicated. Rather, the true values of the analog waveform are only approximated. This approximation is not without its own adverse issues. The difference between the original signal value and the quantized value is called quantizing noise or distortion. This noise or distortion is a highly annoying sound, resulting in impeded system performance. By increasing the number of quantizing steps you can reduce the problem of quantizing noise or distortion. The question to ask now is: How many quantizing steps are enough? Figure 2.24 illustrates an extreme example of quantizing noise.

Quantization of a voice conversation presents enormous challenges, because voice has a wide and dynamic range. A transmission system must be capable of supporting conversations as low as a whisper and as loud as shouting. During the 1950s, listening tests conducted by the telecommunications

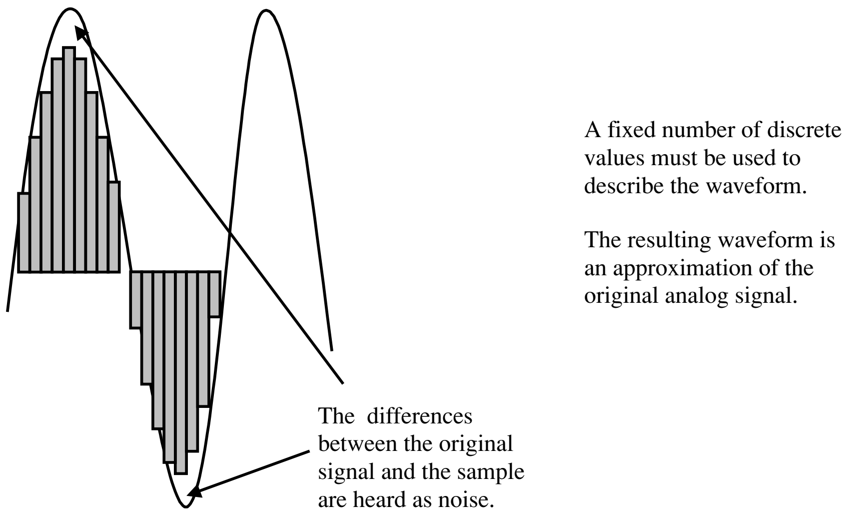


FIGURE 2.24 Quantizing Noise

industry showed that at least 2,000 digital steps would be needed to represent a voice conversation. If you use a linear approach to sampling for quantization, this means that at least an 11-bit code would be needed to sample the waveform—11 bits per sample would be needed. A sampling rate of 8,000 samples per second would result in 88,000 bits per second; we would need an 88,000-Hz bandwidth pipe for a single conversation. In the 1950s and 1960s telecommunications engineers recognized that another approach to quantization had to be taken. This new approach resulted in certain decisions:

- Acknowledge that the full range of the human voice did not have to be supported.
- Ignore the very loudest levels of the human voice. In other words, the telephone is for conversing not for shouting until you're "blue in the face" or whispering so softly that you're only audible to dogs.

These decisions provided practical criteria for designing the transmission systems. The original T-1 designers recognized the need to compress the voice range supported. This nonlinear approach supported the lower range of the human voice, while the upper range would still be supported but with fewer quantizing steps than the number of steps used to support the lower range. Figure 2.25 illustrates both the linear and nonlinear approaches.

Transmission designers used an old analog technique called companding to support the nonlinear approach described. Companding is a compound word standing for compression and expansion. The compression occurs on the transmit side of the conversation. Expansion takes place on the receive side of the transmission. The compression of the lower-end range of human speech can be performed with little adverse impact on fidelity. Expansion returns the speech to its normal signal condition on the receive side. Let's view this from another perspective.

We can assume that we are working with a 2^8 (256 quantized steps) binary code. Since we are favoring the lower-end range of human speech, a larger proportion of the 256 quantized steps will be associated with the lower range of human speech. The louder or higher-end range of human speech will be supported, but only the "loudness" and not the "richness" of tones will be

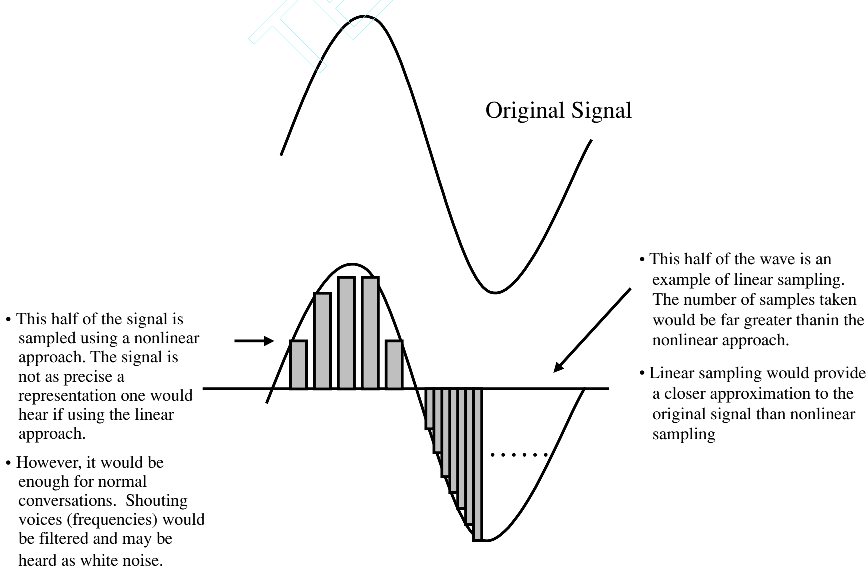


FIGURE 2.25 Linear versus Nonlinear

clearly perceived. This results in more of the 256 code steps being dedicated to representing the low-end range; it does not include the high-end range of speech. By dedicating most of the 256 quantized steps to the lower range, one is capable of hearing the various tones, inflections, and richness of human conversation (not shouting). As we can see in Figure 2.26, the reason that the scale is nonlinear is that the bulk of the quantized steps are in the lower range. Note that nearly 70 percent of the steps are in the lower range while the remaining steps are spaced further apart as one climbs up into the upper range. This is analogous to having lots of granularity for the lower range of human voice and less granularity in the higher range.

DIGITAL ENCODING. The digital encoding of the signal occurs at the same time as the companding. It is part of the companding process. When compression and expansion of the waveform occurs, the process follows a logarithmic curve; hence the ability to maintain the nonlinear nature of the quantization process. The logarithmic curve I refer to is pseudo in nature; think logarithmic from a conceptual standpoint.

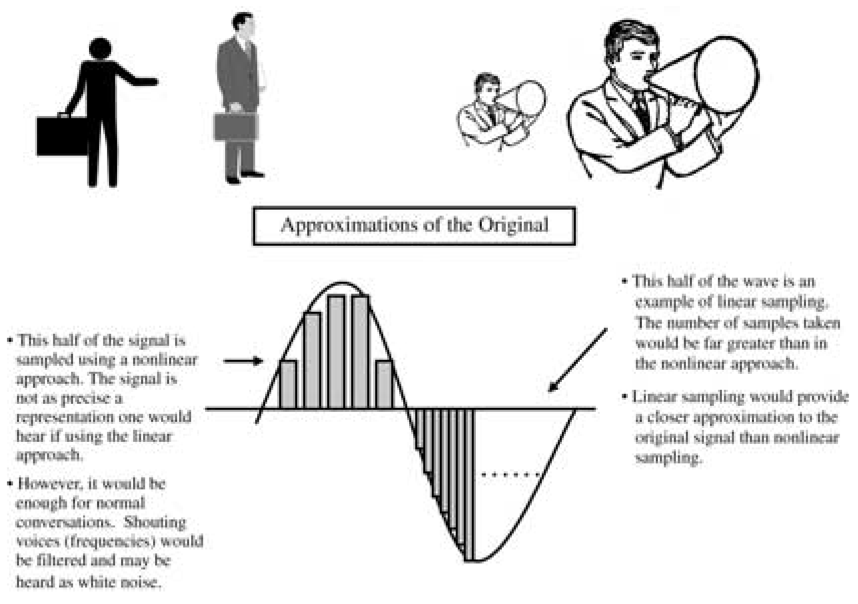


FIGURE 2.26 Nonlinear versus Linear

The logarithmic curve follows one of two mathematical laws; the A-law or the μ-law. North America and Japanese transmission designers follow the μ-law, while the rest of the world follows the A-law. This is not the place for a debate over which is superior because the question is not relevant. North American, Japanese, and European systems meet the needs of their customers, and that is all that is important to a carrier.

OTHER MODULATION TECHNIQUES

There are other modulation techniques; however, as I noted in past books (*Telecommunications Internetworking* and *M-Commerce Crash Course*), the benchmark for service was and still is "voice." PCM provides the best overall quality for voice. Transmission designers have also discovered that PCM coincidentally provides good quality for low-speed data applications, because PCM is a nonpacketized modulation technique.

Other modulation techniques include DPCM, ADPCM, CVSD, VQC, and HCV. These techniques are described in the following section.

DIFFERENTIAL PULSE CODE MODULATION (DPCM)

Voice has a dynamic range but varies slowly. Even though the voice signal can vary across a wide volume range it does so in small increments. This also means that for the same level of accuracy fewer data bits are needed to describe the difference between one sample and another than the number of bits needed to describe the full range. This observation resulted in old transmission designs that only support 4-bit sampling; DPCM supports 4-bit modulation as opposed to PCM's 8-bit modulation.

The development of DPCM was cost driven; it requires fewer resources than PCM. Unfortunately, DPCM cannot support modem signals. Modem signals can vary widely and quickly. A DPCM-based design cannot follow the signal changes very well in a modem signal stream and noise results. Another way of looking at this is that DPCM will pass only the change since the last sample taken, while PCM transmits the absolute value of every input. See Figure 2.27.

ADAPTIVE DIFFERENTIAL PULSE CODE MODULATION (ADPCM)

Adaptive DPCM (ADPCM) is considered an improvement over DPCM. It is capable of varying the assignment of the four bits to meet different volume changes. For example, if multiple and successive voice samples were very wide apart, the differential typically described by four bits could not keep pace with the actual change. The ADPCM software algorithm is capable of varying the number of bits being used in the sampling. This technique can help reduce quantizing noise from loud signals.

CONTINUOUSLY VARIABLE SLOPE DELTA MODULATION (CVSD)

There will be instances where all that is required is a single bit to describe a sample. In those cases, you can send lots of samples about a small signal in bandwidth pipe capable of handling large volumes of data. Unfortunately, this also means that one is restricted to signals that are not loud. CVSD looks at each

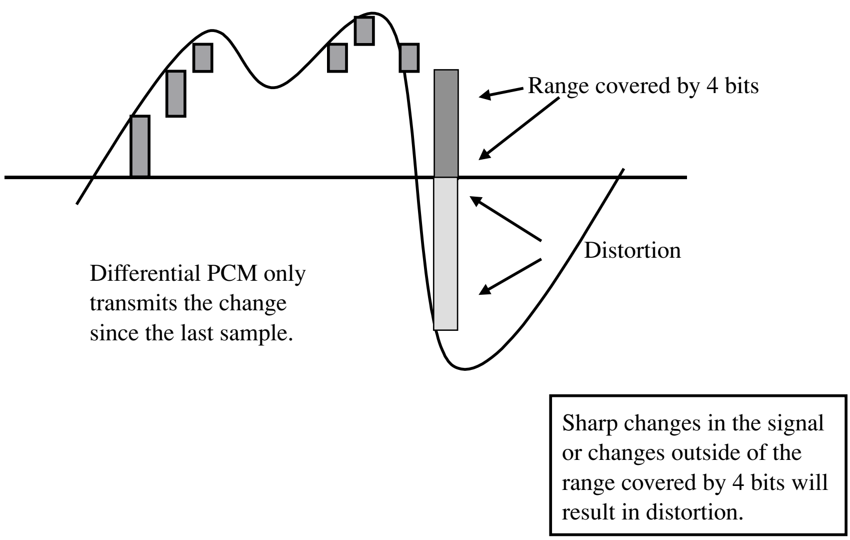


FIGURE 2.27 DPCM (Differential Pulse Code Modulation)

individual bit and only sends information about the rate of change.

Think of a curve describing a voltage signal. The curve has a slope. The slope of the curve changes in very small increments; for example the increment can be as small as a small voltage in a 1/32,000 second period (32,000 bits per second). In order to measures the changes in voltage, one needs to send a reference signal (voltage), and then every change is measured against the reference signal.

VECTOR QUANTIZING CODE (VQC)

The VQC methodology is based on PCM. The difference is, rather than transmitting individual samples, VQC systems transmit information regarding a series of samples. A vector is defined as a string of bits (0s and 1s) that form a pattern. The vector that results is compared to vectors stored in the transmission system's database. The closest match is found, and the code for that stored vector is sent to the receiving end. In other words, one is matching patterns stored in a database.

HIGH-CAPACITY VOICE (HCV)

As the name implies, HCV is focused on providing high-quality voice at 8,000 bits per second, theoretically a quality level higher (better) than plain old PCM. HCV expands on the principle of vector coding techniques used in VQC by many more forms of waveform coding that model human vocalization. Human vocalization is comprised of numerous sounds, all generated by things other than vocal cords. (The vocalization process is comprised of lungs, vocal cords, lips, sinus cavities, tongue, and teeth.)

HCV requires highly intensive computing processing, but it can be done.

Table 2.1 describes the various modulation techniques.

TABLE 2.1 Various Modulation Techniques

ENCODING METHOD	BITS PER SAMPLE	SAMPLING FREQUENCY	TOTAL BIT RATE
PCM	8	8,000	64,000
CPCM/ADPCM	4	8,000	32,000
CVSD	1	9,600 through 32,000	9,600 through 32,000
VQL	3.5	6,667	32,000
VQC	Variable	8,000	8,000 through 16,000
HCV	1 and 2	8,000	8,000 through 16,000

TRANSMISSION: LOCAL VERSUS LONG DISTANCE

Transmission is typically viewed from a long distance perspective, connecting cities and countries. However, it also has a local aspect, called the local loop. Both forms of transmission have different requirements from customer and technical perspectives. This section of the book will describe local transmission and long distance transmission systems.

Generally, the longer the distance between the transmitting and receiving ends the greater the distortion impairments.

LONG DISTANCE

In North America, a long distance call used to mean anything handled by AT&T, not the local telephone company. That definition applied before 1984 and divestiture. Today it means anything outside your calling area and outside the jurisdiction of the local telephone company. The more technical definition (neither political nor customer perceived) does not consider corporate boundaries or jurisdictions. Rather it requires an examination of the overall system, distances, and transmission requirements. This is not the place for an explanation of how requirements are calculated; however, I will describe impairments. By understanding impairments one can gain an understanding of the differences between systems.

The following impairments can limit the ability of a long distance system. Each one can be technically addressed and resolved by transmission designers.

- *Jitter.* Jitter is a short-term differential of the sampling time instant from its intended position in time. In other words, sampling is out of time-phase with the intended sampling time periods. Jitter can cause degradation in system error performance, errors in timing recovery circuits, and distortion of the analog signal at the receiving end.
- *Distortion.* Distortion of the signal can occur either through loss of amplitude and delay distortion. Distortion is used in reference to analog systems and can generally be defined as adverse variations in the way a transmission system is measuring the signal at both the transmit and the receive ends. Note that even though a long distance system tends to transmit over a digital facility, it is converted to an analog system for over 95 percent of the homes in North America and around the world.
- *Noise.* Noise was described in greater detail earlier in Chapter 2.
- *Crosstalk.* Crosstalk occurs when signal paths are crossed and each party can hear itself while hearing other extraneous parties. Crosstalk was described in greater detail earlier in Chapter 2.
- *Echo.* Echo was described in greater detail earlier in Chapter 2. Echo can be resolved using echo cancellers, the correct gauge of wire, and correct bridge taps, and by balancing the connections of various gauges of wire.

LOCAL LOOP

The local loop engineering criteria are focused on loop resistance in metallic facilities. (There is very little fiber optics to the home or business, when one compares the total facility population in the local loop.)

From a customer and regulatory perspective, a local telephone call is anything that a long distance call is not. The local loop is the portion of the physical telecommunications circuit between the LEC's central office (local switch, also known as a Class 5 switch) and the customer's premise. This circuit was originally twisted-pair conductors; essentially a continuous loop of wire. The original local loop was solid metal (copper) wire and is still the primary facility. Figure 2.28 is a representation of the local loop.

The basic loop design rules are Loop Resistance Design, Configuration Range Extension with Gain, and Long Route Design. These rules are applied in conjunction with routing plans used in the local loop. These rules have specific design criteria associated with each rule set. You do not need to understand the specific rule sets, but the need to understand how a local call is routed is imperative. The design of the route affects the local transmission design from the switch to the user. The rest of this section will describe general routing methodology.

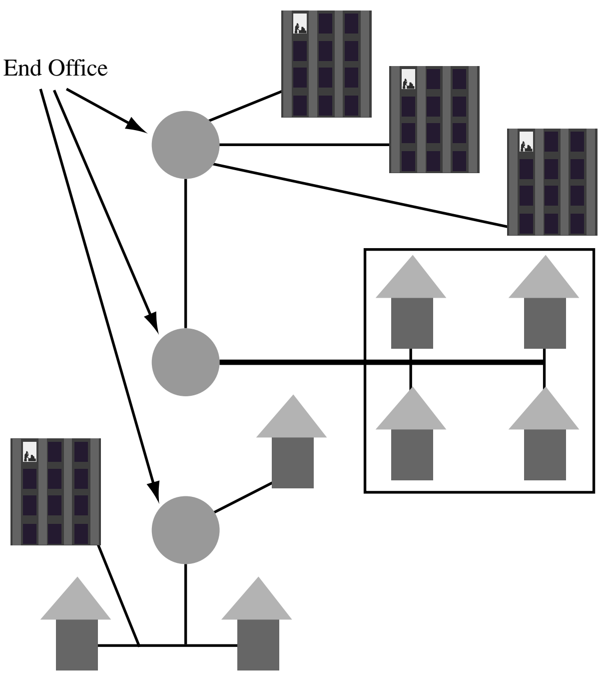


FIGURE 2.28 Local Loop

ROUTING METHODOLOGIES

Routing methodologies are applicable to both long distance and local loop networks. However, the local loop can be greatly influenced by the routing plan given the level of granularity needed when routing directly to a customer premise. Routing methodology exists independent of transmission facility type, whether metal, glass, or wireless.

Given the density of facilities in a local network, cost becomes a guiding factor. In simplistic terms, a large, single fiber optic facility is needed to connect networks in different cities; however, even more metallic and other types of facilities are needed to service a community. The sheer volume of transmission facilities, measured in kilometers or miles, is several orders of magnitude more than a long distance network; 100,000 facility miles in a small community of 20,000 people, including businesses, is very possible.

Routing is the action of directing information from one point to another. There a two principal forms of routing in use in the traditional telecommunications world:

- Hierarchical routing (also known as alternate routing or least-cost routing)
- Dynamic routing

In a more expanded view of telecommunications, which includes the data world, there is a third type of routing, packet routing (i.e., packet switching of information).

Routing is not a transport technology but a method of moving information around the transport structure. The network configuration is inter-related with the routing methodology such that it can be optimally executed. The importance of this topic requires elaboration.

HIERARCHICAL ROUTING/ALTERNATE ROUTING

The original form of routing first used in the old wireline voice telecom environment was hierarchical routing (known today as alternate routing). Alternate routing is applied to voice traffic by providing a first choice (high-usage trunk route) and one or more alternate routes if the first route is unavailable. This form of routing is hierarchical in nature because there is a predetermined order of routing that the switching system follows. Dynamic routing is more flexible and grew out of the need for more efficient routing and management of the enormous volumes of traffic crossing the nation.

Hierarchical routing (alternate routing) has advantages and disadvantages. Advantages are:

- Minimizing the cost per unit of traffic flow in a planned manner. This enables the carrier to closely manage traffic routing costs by deploying additional transmission media assets where necessary.
- Maximizing route usage during specific times of day, days of the week, and weeks of the year. A company must not leave capital assets sitting in the field underutilized.
- Maximizing the scheduling of network management and operations assets. Carriers that know the specific details of when and where traffic is being routed are capable of scheduling activities in areas of their network in which traffic load is at its lowest. Remember, the carrier cannot shut down its network for maintenance; it can only schedule maintenance during low periods of activity.

These are the disadvantages of hierarchical or alternate routing:

- Carriers need to monitor and analyze the traffic patterns in their network on a daily basis. A carrier could save time and money if it could reduce the number of times it had to make network adjustment for the sake of traffic flow. Theoretically, the population does not make drastically large or frequent changes in traffic patterns.
- Routing plans must be accurate. This is not as unusual as it might seem. There have been instances since the divestiture

of the old AT&T Bell System in which carriers have suffered outages due to severed transmission facilities and overloaded networks. Despite the fact that extensive load planning was performed, not enough planning was done to ensure secondary and even tertiary routes. Resources must be available and skill sets must be present in the planning organization.

- Time and money need to be spent to ensure accurate planning.

Figure 2.29 shows a one-way high-usage transmission facility from switch X to switch Y, with an alternate (final) route via a switch that performs a traffic cop function called "tandeming." In general, the direct or high usage route is shorter and less expensive than the alternate route. However, because each segment of the alternate route is used by other calls or information packets, a number of traffic items can be combined for improved efficiency on that route. The basic challenge is to minimize the cost of carrying the offered load.

The decision tree for routing tracks the following line of reasoning: Switch A needs to route information to Switch B (see Figure 2.30):

- Is the high usage route available?
- If the high usage route is available, use it.
- If the high usage route is not available, use the alternate route.
- If the primary alternate route is not available, then use the secondary route. In most cases of voice telecommunications switching there will be no secondary route; the assumption is that blocking has been designed into the network. (There will be more on blocking later.) In the case of data transactions, companies that specialize in transporting financial data will probably have a secondary alternate route.
- A Switch C diagram was added to illustrate the point that in some cases there may be no alternate route. Information traffic engineering and need will dictate whether or not there should be an alternate route.

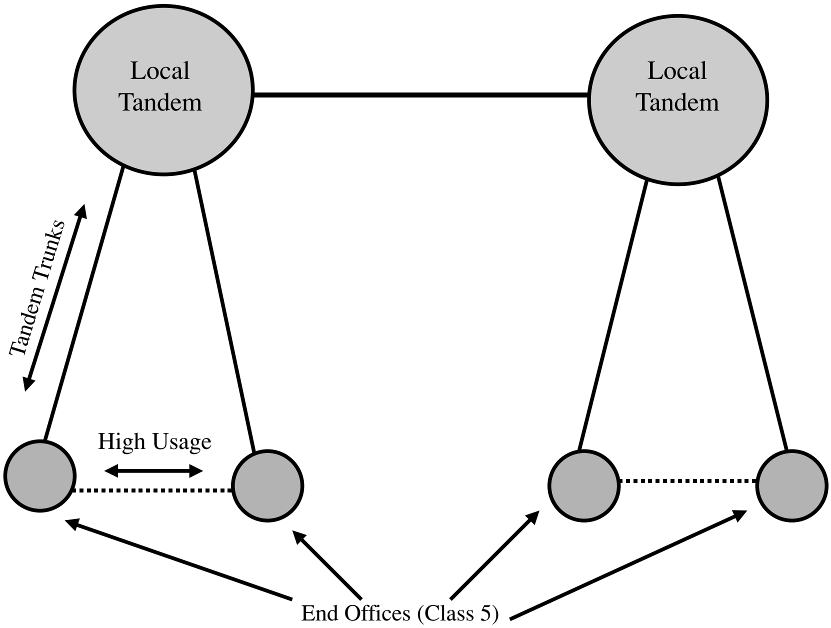


FIGURE 2.29 High Usage Route

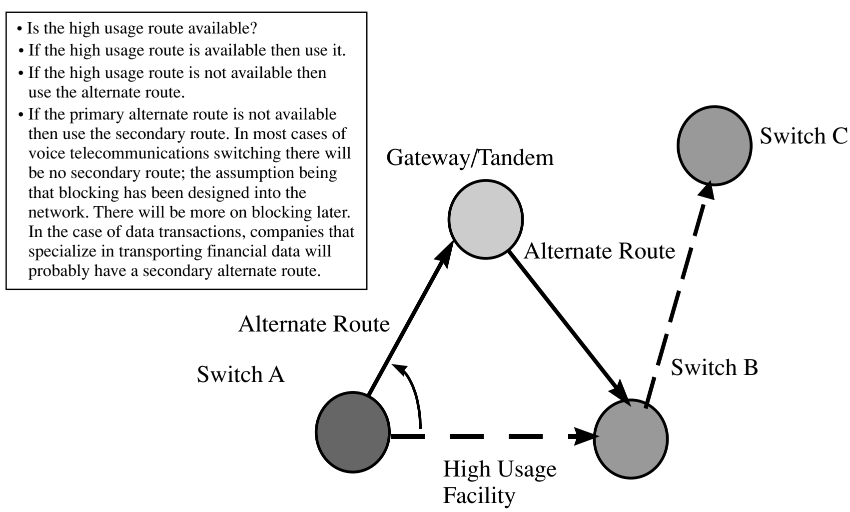


FIGURE 2.30 Routing Decisions

The issue of alternate routes brings up the question of when is enough, enough? There is a relationship between the number of trunks, the cost of the direct route, the cost of the alternate route, and the total dollar cost for serving the given offered load. As you will see, the high-usage facility cost is proportional to the number of high-usage trunks. If there are no high-usage trunks, all the traffic must be sent on the alternate route, so the incremental alternate route monetary cost is high. If a high-usage group is available, the incremental cost of the alternate route is lower because, theoretically, less traffic is sent over the alternate route. The cost of alternate routing decreases the minute the first trunk is added to the high-usage trunk group. The flip side of this cost picture is that there is a point at which there will be too many high-usage trunks in the high-usage group. As more high-usage trunks are added, each additional trunk will theoretically carry less traffic, while each alternate route trunk will continue to carry a significantly larger amount of traffic.

At some point it becomes cost prohibitive to add any more high-usage trunks.

DYNAMIC ROUTING

Dynamic routing refers to the updating of routing patterns on a real-time or near real-time interval on the basis of traffic statistics collected by a network management system. Dynamic routing is a traffic routing method in which one or more central controllers determine near real-time routes for a switching network, based on the state of network congestion measured as trunk group busy–idle status and switch congestion. The choice of traffic routes is not predetermined.

Dynamic routing schema are used in situations in which the complexity of routing the call is so high that applying the fixed rules and structure of hierarchical network configurations makes it difficult for a network manager to manage call flow properly. To some extent there must be a degree of intelligence embedded within the network.

Figure 2.31 compares the complexity of routing information in a hierarchical routed network with routing information in a dynamic routed network.

Figure 2.32 is an illustration of an even more complex set of network relationships, a pictorial description of the Internet. In today's World Wide Web of Internet sites there appear to be links between multiple sites regardless of whether or not there is any relationship at all.

BLOCKING. Blocking is a grade of service measurement used by traffic engineers. Blocking assumes a portion of the calls being made to the switch will be blocked from completion due to unavailable switching circuits. Blocking is designed to a probability established by the carrier. Zero blocking assumes that if every customer attached to the switch were to make a telephone call at the exact same moment each customer would be able to complete the call. However, to design a network to such a configuration would be cost prohibitive.

In a network with a blocking probability of 10 percent we could assume that if every customer attached to the switch were to make a telephone call at the exact same moment 10

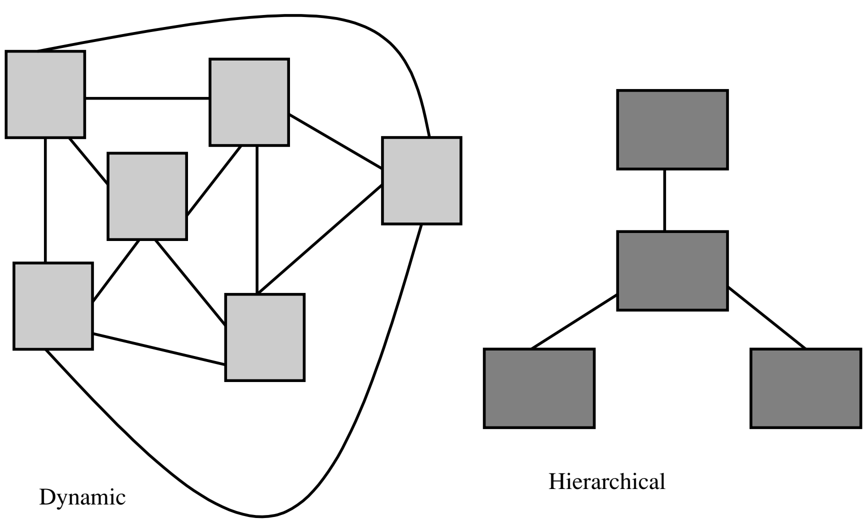


FIGURE 2.31 Dynamic Routing versus Hierarchical Routing

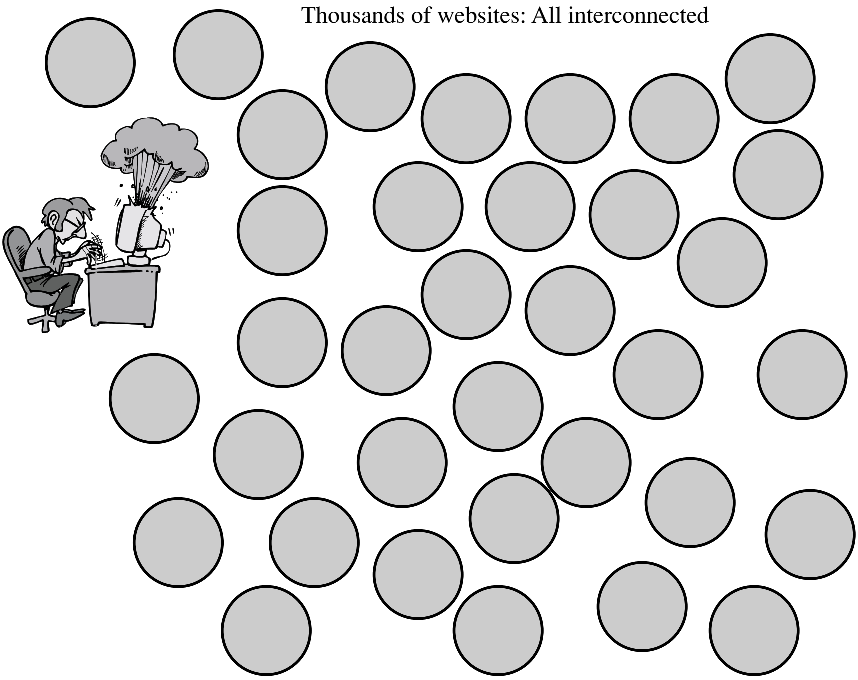


FIGURE 2.32 The Internet

percent of these customers would be blocked from completing the call. The network cost differential is significant.

PACKET SWITCHING

Packet switching represents one step beyond traditional voice telecom switching and is suitable for a data environment (including the Internet). Packet switching involves the transport of information in discrete packets or packages of information. Each packet is identification-tagged with its label, origination, and destination. The packet is launched into a network conditioned to support packets of information (rather than a continuous stream of information), and ultimately finds its way to the destination of choice. Each packet takes a different route to the final destination. This is not exactly a dynamic routing schema but close enough, because the routes are not predetermined and change constantly.

ROUTING ISSUES

Hierarchical routing and dynamic routing are used in circuit-switched calls and connections. Packet routing is used by non-circuit-switched calls.

It is important for transmission designers to know what will be transported on the network they design. Is it a data network? Is it a voice network? How many customers will the network support?

The requirements for the transmission system will influence the design of the network and the cost structure for the construction of the network. The cost of the network is probably the biggest part of the technology decision. Furthermore, it is not just a simple matter of cost; in reality it is an issue of analyzing cost–benefit to the network owner.

The fundamental rules that govern telecommunications traffic engineering are:

1. Reduce the number of links (trunks) needed to connect all users of the network.
2. Reduce the length of the links (lines and trunks) needed to connect users to the network.
3. Maximize usage of network facility resources in a given period of time by increasing the number of different connections (trunks) to allow users to communicate with each other or other resources.

Understanding how a network is designed will enable you to understand the reasoning behind why a network was designed. For example, two wireless service providers provide service to two different markets. However, the markets have exactly the same type of subscriber base and provide the same types of services, yet their networks are as different as night is from day. Why?

The answer could be:

- Simple economics, or
- The result of a difference in business plan; for example the service provider may be emphasizing data rather than voice.

Before planning any network, the service provider should know "what business one is supposed to be in." In addition to customer requirements, the type of telecommunications segment in which the business operates will dictate the technologies employed and the type of network configuration optimal for the segment.

SUMMARY

The purpose of this chapter was to provide a basic understanding of transmission system concepts. Transmission design is the unsung hero of telecommunications and the least talked about aspect of telecommunications service provisioning. Simply put, transmission engineering is not considered "sexy." However, without a properly designed transmission network, none of the sexy technologies like Internet routers and servers or soft switches will ever amount to anything. New types of services will never see the light of day unless there is a physical transmission network in place to support the machinations of the new high-tech switches.

CHAPTER THREE

FIBER BROADBAND NETWORK TECHNOLOGIES

The purpose of this chapter is to describe the various and popular network transport technologies used by the "optical world." The concept of optics in communications has been around centuries longer than the telephone or the telegraph. We are going to review the history of fiber optics and the basic physics of light wave transmission before describing the transmission protocols that support fiber optics.

OPTICAL HISTORY

Transmission of communications signals via optics dates back to the 1700s. In the 1790s Claude Chappe of France invented the optical telegraph, which employed the use of semaphores mounted on towers with human operators relaying messages between them. This system required the use of human operators within line of sight of one another. The messengers used a combination of motions and an apparatus, usually a flag or lantern. The Navy still uses semaphores in the form of signal flags and lights. Optics is defined as something which is "seen." The use of the word "optics" in conjunction with the word "fiber" came into being in the twentieth century.

In 1870, a physicist named John Tyndall demonstrated that a light beam shone into a stream of water would follow the stream of water. Tyndall had shown how the air–water interface was able to reflect the light beam in such a way that the light stayed within the stream of water. Actually, the light was reflected back into the water. The phenomena demonstrated the concept of internal reflection.

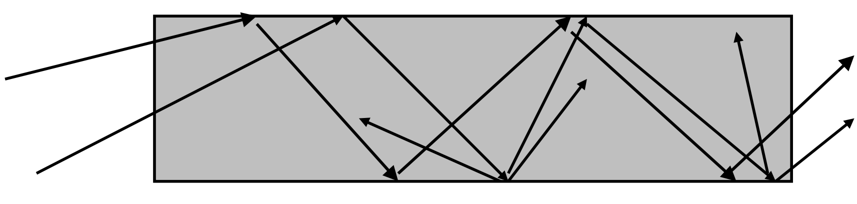
In 1878, the inventor of the telephone, Alexander Graham Bell, took the concepts of light and optics in communications even further when he created a device that was able to use light to transmit the human voice through air. Bell called the machine the Photophone. The Photophone employed mirrors, which were arranged in such a way that light was focused onto a diaphragm. This diaphragm was attached to a mouthpiece, which, when spoken into, caused the diaphragm to vibrate. At the opposite end of the device was a speaker where one could listen to the speaking party. The speaker was connected to a resistor, which was connected to a battery. When the speaking party spoke into the mouthpiece, the sound vibrations from the speaker's voice would cause the light beam shining on the resistor to vary in intensity. The resistor would react to the varying light intensity and vary the electrical current from the battery. The varying current intensity caused sound to be emitted from the speaker. A twentieth century take on this concept is laser-based communications in air and for limited outer space applications. The atmosphere is not the best medium to use for such a transmission system for obvious reasons related to weather and obstacles.

From the mid 1800s through the early 1900s, work was conducted by a number of scientists and inventors to carry light beams using reflective and hollow metal pipes from one location to another, eventually leading to work on transmitting images via transparent rods. By the 1940s, the industry successfully demonstrated how transparent plastic could carry a light beam from place to place. As the years passed, it was found that glass could be created with far more clarity than plastic.

Since the beginning of the twentieth century, telecommunications engineers had been seeking ways of carrying increasing numbers of conversations over a single medium. The goal for these engineers was delivering more bandwidth. The various telephone companies were driven to find more cost-effective ways of delivering calls to customers. It was not until the late 1950s that laser light sources had become highly focused enough to use as a communications light source and glass fibers had reached a level of purity to be considered practical for telecommunications.

UNDERSTANDING THE PHYSICS OF FIBER OPTICS

Internal reflection is the basis of light transmission through a nonatmospheric and solid medium. Figure 3.1 shows internal reflection at work. Beginning with a hollow reflective metal pipe, as light is shone through one end of the hollow pipe the light rays are bouncing off the interior wall of the pipe; eventually the collection of light rays is emitted at the other end. Taking this one step further, a solid but transparent glass rod is used as the medium for transmission. The light beam is shone through one end of the glass rod. As the light is traveling through the rod, most of the light makes its way to the other end of the glass rod. Some of the light escapes through the walls of the pipe but most does not. This phenomenon is called refraction. Figure 3.2 is an illustration of light traveling through a glass rod.



A hollow metal pipe can transmit light; however, some of the light will reflect back and there will be scattering.

FIGURE 3.1 Internal Reflection in a Hollow Metal Pipe

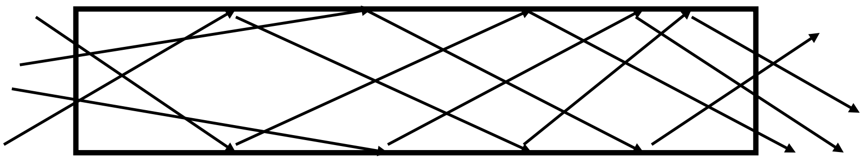


FIGURE 3.2 Light Traveling through a Glass Rod

Refraction of light occurs when light is shone through two different transparent media and that light appears to bend as it passes from one medium to another. An example of refraction is when you see the image of a stick bending when it is inserted into a pool of water. Another example is when you look at half of an object through thick glass. The image and the object appear to be bent with respect one another.

Refraction of light occurs when the refractive index of one medium is different from that of the other medium. Air, water, and glass have different refractive indices. The refractive index is the ratio of the speed of light in vacuum to the speed of light in the other medium. Light travels more slowly in media other than a vacuum. The following formula shows how the refractive index is calculated:

Refractive Index = Speed of light in a vacuum (= c)/Speed of light in selected medium

Since fiber optics is used in atmosphere, the refractive index is calculated for practical applications as follows:

Refractive Index = Speed of light in air/Speed of light in selected medium

As I noted, refraction refers to the bending of light when it passes from one medium to another; this assumes that each medium has a different refractive index. Vacuum has the lowest refractive index. Air has the second lowest refractive index of any medium. For illustrative purposes, we will assume that air and vacuum have the same refractive index.

The amount by which the light beam bends is dependent on two factors:

- The difference in the refractive indices of the materials.
- The angle of incidence, which is the angle at which the light strikes the media. Angle of incidence is measured from the centerline of the medium. This centerline is an imaginary line that runs perpendicular to the entry surface of the medium.

Figure 3.3 describes angle of incidence.

Figure 3.4 describes the relationship between the angle of incidence and the angle of refraction. Note that there is a need to understand these concepts because they are part of the basis for understanding how light travels through glass transmission systems. When the angle of incidence is too high (or steep), light can escape through the walls of the glass transmission system. If light escapes the fiber optical medium (glass medium), that means there is signal degradation. Furthermore, when the angle of incidence is too high, there is not only signal degradation but also absolutely no refraction. Refraction will take place when the angle of incidence is "just right."

When the angle of incidence is "just right" and no light escapes the glass facility, a phenomenon called internal reflection occurs. The concept of internal reflection lies at the heart of glass transmission systems.

THE STRUCTURE OF A FIBER OPTIC TRANSMISSION FACILITY

A fiber optic transmission cable is thinner than a human hair strand. However, this strand of glass has more bandwidth capacity than a 24-gauge copper wire. A fiber optic cable is composed of:

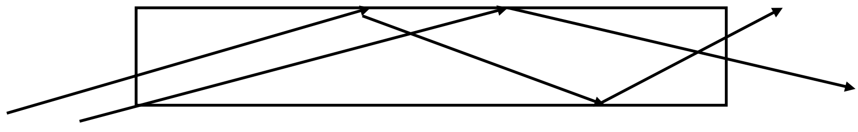


FIGURE 3.3 Angle of Incidence

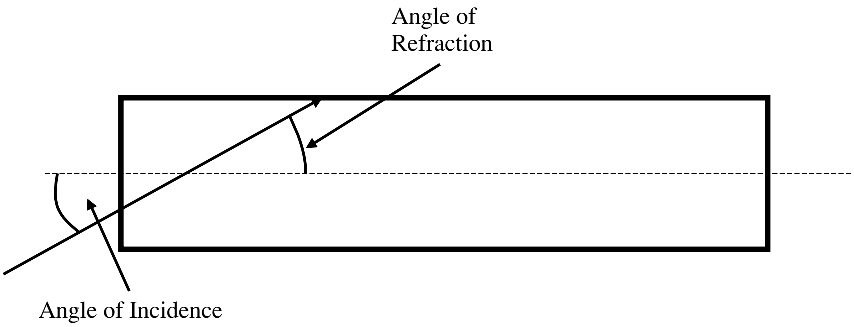


FIGURE 3.4 Angle of Incidence and Angle of Refraction

- An inner core (conductor)
- An outer cladding
- Some type of insulation

The inner core is glass of one refractive index, while the outer cladding is glass of a different refractive index. The outer cladding acts to refract light back into the inner core. No matter how well one controls the angle of incidence of the light beam, there will be some light that escapes from the inner core. Therefore, the outer cladding is very important. The outer cladding has a refractive index lower than that of the inner core. Figure 3.5 is an illustration of a fiber optic cable. The higher the refractive index, the slower the speed of light.

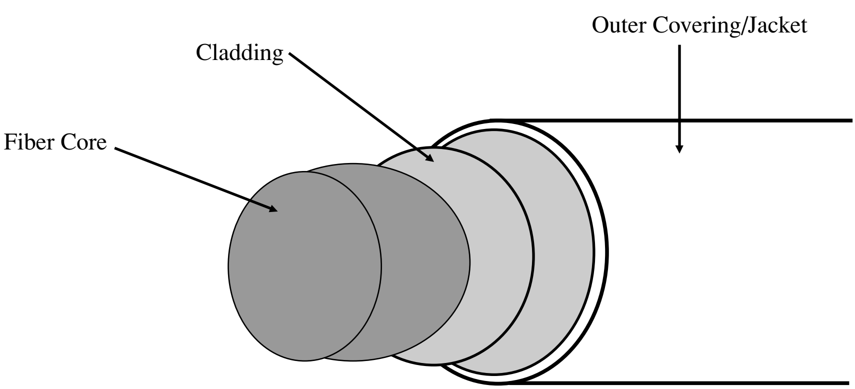


FIGURE 3.5 Fiber Optic Facility

FIBER OPTIC LIGHT SOURCES

As important as the structure of the physical fiber optic facility is, without a proper light source the facility would be little more than a piece of thin glass sculpture. Light sources come in two flavors today:

- Light emitting diodes (LEDs)
- Lasers (Light Amplification by Stimulated Emission of Radiation)

When the light source is quickly turned on and off, the binary bits of 0 and 1 can be transmitted.

LIGHT EMITTING DIODE (LED). An LED is a semiconductor diode that emits light when an electrical current is passed through it. LEDs are multilayered compound structures (of various crystalline-based materials) bonded to a silicon-based substrate layer. LEDs are used in fiber optic systems that support data streams no faster than 500 Megabits per second. LEDs use far less power than the typical incandescent light bulb or even fluorescent light fixtures. LEDs can be found in alphanumeric displays.

There are two types of LEDs: surface emitting and edge emitting. Surface emitting LEDs emit unfocused light at a very wide angle. They are useful in alphanumeric displays or general indicators and visual signaling systems. The edge emitting LED is the opposite of the surface emitting LED. Edge emitting LEDs produce light that is focused. Figure 3.6 is an illustration of LEDs.

LASER (LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION). The laser is a device that produces highly focused single-wavelength light. Laser-generated light is focused and coherent. Coherence refers to light waves that are in phase. When a light bulb or any light source produces light, it emits light in thousands of different wavefronts. The wavefronts of light from a typical household light bulb are not in phase (not in sync) with one another; the wavefronts are overlapping one

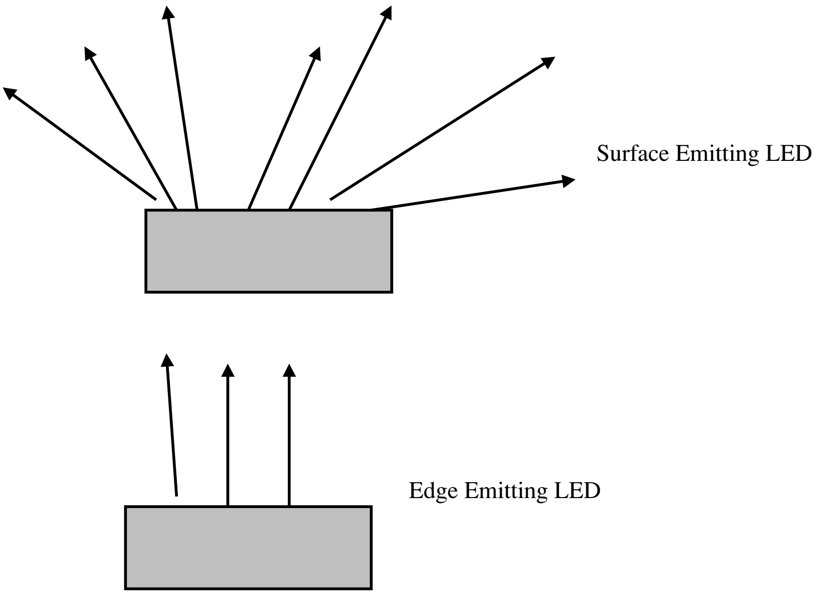


FIGURE 3.6 Light Emitting Diodes (LEDs)

another. In coherent light, the light wavefronts are all in phase with one another. Coherent light can be likened to the perfect alignment of a sine wave, in which all the peaks and all the troughs of the wave are aligned. Figure 3.7 is an illustration of the laser.

Operationally, the laser is superior to LED-based systems. Lasers produce highly focused and coherent light; therefore they are capable of producing light that can be directed into the fiber with minimal loss. In LED-based systems, much of the light produced will not make it through the fiber interface because so much of it is scattered.

GRADES OF FIBER

Optical fiber is graded as either multimode and single mode. Each has different bandwidth and physical properties. The core of a single mode fiber has a diameter narrow enough to restrict light to one mode of travel. In other words, we have a one-way transmission facility. Multimode fibers have a much

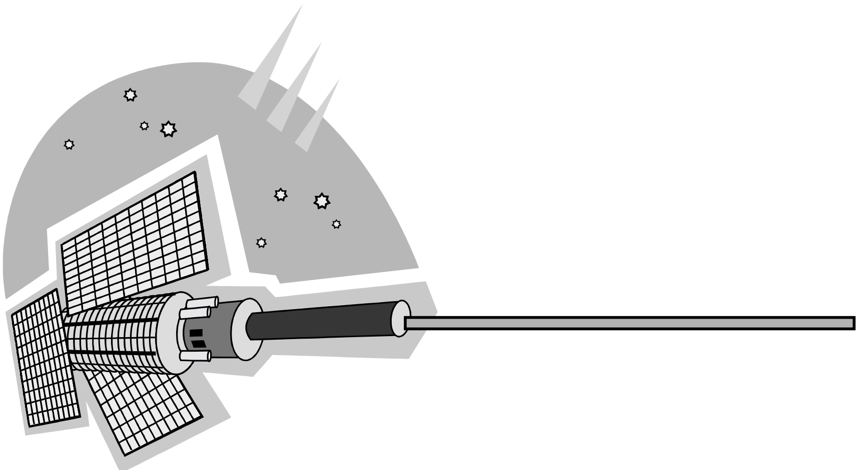


FIGURE 3.7 Laser Light

wider diameter. Due to its wide diameter, multimode fiber is capable of allowing light to enter at different angles and travel through the fiber along different criss-crossing paths.

MULTIMODE

Multimode fiber supports more than one mode. Single mode supports one mode. As the name implies, multimode supports multiple paths of light (noncoherent and unfocused light) entering a fiber optic facility at different angles. Multimode is far more forgiving as it relates to the light source used. Multimode fiber is capable of supporting light from an LED. It is less complicated to use and less expensive since lasers are not needed.

Despite the operational ease, multimode fiber is subject to multimode dispersion. When the light from an LED is passed through a multimode fiber optic transmission facility, multiple paths are taken. If one could see the bundles of light rays traveling through the multimode fiber, one would see the various bundles bouncing around the interior wall of the fiber facility. Each bundle would be taking a different path. Each bundle of light would arrive at the receiver at different times. The result would be a signal dispersed over a short distance. Figure 3.8 is representation of multimode fiber.

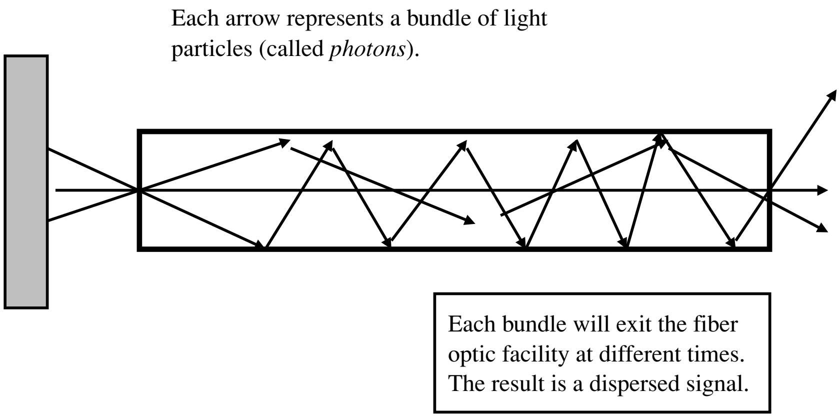


FIGURE 3.8 Multimode Fiber

There was a time early in fiber deployments in which multimode was supportable in a business case. During those times, fiber was new, customer demand was less, customer expectations for quality were lower, and ease of maintenance was important. Multimode was sufficient years ago, but high demand for large bandwidth has caused multimode to fall out of favor as the primary form of optical fiber. Multimode is still used and is manufactured in two forms: multimode step index and multimode graded index.

MULTIMODE STEP INDEX. Multimode step index is manufactured with a core that has a refractive index higher than the cladding. If light enters the core at a high angle, then some of the light will escape out of the core and enter the cladding. The light in the cladding travels faster than the light in the core. Actually, step index fiber is the original fiber used by carriers in the early 1980s. The problem with step index fiber is that the light rays are traveling through the fiber bouncing around the core and cladding. The receiving end of the fiber facility finally sees a highly dispersed signal over a long distance. Note that in the 1980s fiber optical facilities were being used in networks that by today's standards were short-distance hops of less than 20 miles per span. As fiber became more popular and increasingly used to support banking and financial customers, signal dispersal became a big problem. To fix this problem multimode graded index fiber was created. Figure 3.9 is an illustration of step index fiber.

MULTIMODE GRADED INDEX. Multimode graded index fiber was created to overcome the signal dispersal shortcoming of multimode step index fiber. Graded index fiber is manufactured with a core that has a varying refractive index. As one moves outward from the center of the core the refractive index actually decreases.

This design enables light to enter at multiple angles and travel from the center of the core to the outer areas of the core in such a way that the light is accelerated as it moves away from the core's center. Rather than there being an enormous amount of reflection (bouncing), the bulk of the light's rays are actually traveling within the core of the fiber with minimal bouncing. Reflection is not eliminated but drastically reduced in comparison to step index fiber. In fact, the paths of the light rays look almost parabolic. Figure 3.10 is an illustration of graded index fiber.

The result is a signal that suffers less from signal dispersion than if it were traveling through a step index fiber. In addition to the varying refractive index, the fiber is also relatively thin. (Multimode fiber is thick; step index is thicker than graded index fiber.)

Graded index fiber has a core ranging from 50 to 62.5 microns thick with a cladding ranging from 20–125 microns

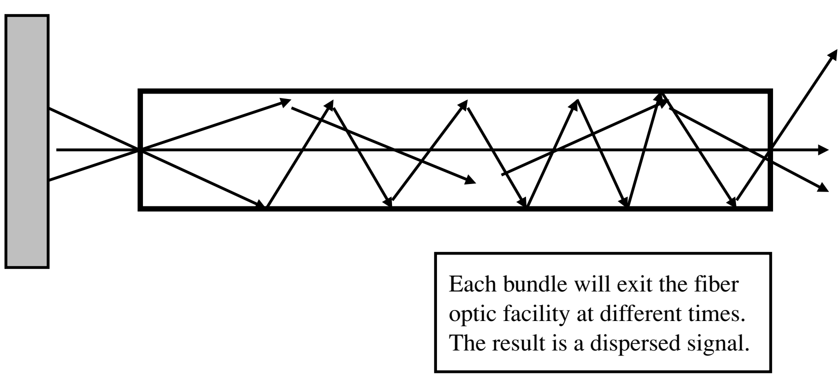


FIGURE 3.9 Multimode Step Index

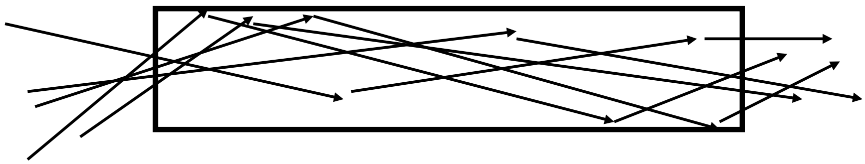


FIGURE 3.10 Graded Index Fiber

thick. The step index fiber has a core ranging from 120–400 microns thick. The cladding can have a thickness ranging from 20 to 800 microns.

SINGLE MODE FIBER

Single mode fiber is much thinner than multimode fiber. Single mode fiber can have a core thickness ranging from 7 to 10 microns. The outer cladding can be as thick as 125 microns.

Single mode fiber is only capable of carrying a single mode of light. Since it carries only a single mode of light, all the dispersion issues encountered by multimode are eliminated. Due to the elimination of the intermodal dispersion problems of multimode, single mode is capable of supporting large bandwidth for long distances. Where multimode fiber could use an LED as a light source, single mode fiber must use a laser as the light source. Single mode fiber suffers less from the dispersion issues encountered by multimode and is therefore capable of carrying large bandwidths of light farther and with less interference than multimode.

Single mode is harder to deploy because of the inherent problems of coupling a laser to the transmit end of the fiber; aligning the laser and coupling it to the fiber is not a simple chore. Due to the reduced dispersion problems, the light is traveling faster down a single mode facility than it travels in a multimode fiber facility, resulting in faster data rates.

Figure 3.11 shows single mode fiber.

Single mode fiber has it own share of issues. It is susceptible to material dispersion when different wavelengths of light are traveling through a fiber optic facility. These light rays arrive at the receiving end at different times because different wave-

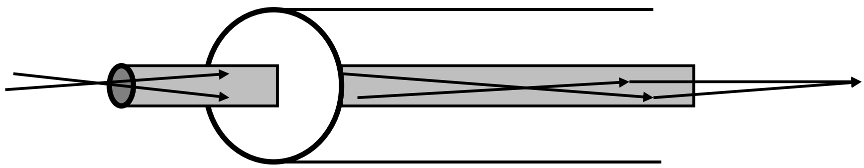


FIGURE 3.11 Single Mode Fiber

lengths of light travel at different speeds. When an LED is used in a fiber optic facility, several wavelengths of light can be emitted. The laser is capable of transmitting a single wavelength; therefore, the material dispersion is reduced (not eliminated) in a fiber facility using a laser as a light source. However, this does not mean that material dispersion cannot occur. Laser light is transmitted across a very narrow spectrum of no more than 5 nanometers in spread. Laser light can disperse, naturally from a line width perspective, through the glass material.

Even though I noted that lasers transmit single wavelengths of light, the laser light is still traveling down a fiber optic facility that is bent around corners, and even in a straight path it is not necessarily level or without bends. There is still internal reflection, just not as much as in an LED-coupled fiber optic facility. Dispersion can result from reflections and refractions. Waveguide dispersion occurs when the refractive indices of the outer cladding and core cause the refracted light rays to arrive at the reception point at different times.

When light is transmitted down a single mode fiber it is possible that the grade of single mode fiber may have an effect on signal dispersion.

Figure 3.12 illustrates these points.

The forms of dispersion described can also adversely affect the functional support of multimode fiber.

FIBER OPTIC USES

Fiber optic transmission systems have only recently been finding enormous popularity in the marketplace. Prior to the year

- Material dispersion—Material affects different wavelengths of light differently.
- Internal reflection and refraction can increase with bending of fiber.
- Waveguide dispersion increases when the refractive indices of the outer cladding and core are such that the refract light arrives at different times.
- Grade of fiber is the quality of the fiber; clarity and refractive index.

FIGURE 3.12 Single Mode and Dispersion

2000, the economics of fiber dictated fiber optic deployment in the following applications:

- Long distance backbone network, which includes the regional and national backbone network business; the submarine cable business is also included in this category
- Major metropolitan network deployment in heavy business areas
- Specific customer applications for data transmission—once known as special assemblies

These deployments are large network deployments designed to service the business community. The cost of fiber and the need to maintain a specific return on investment has driven fiber deployment. For several years fiber could only be justified in areas in which large networks were being connected or in the business market where there were data consumers willing to pay for the fiber facility.

However, this situation has changed drastically due to the overwhelming interest in the Internet business segment. The key to driving the Internet marketplace is driving more bandwidth into the network. Many engineers take the position that the inherent advantages of fiber would be more than sufficient to justify its wide-scale deployment. In reality, as numerous as the advantages of fiber deployment are, it is and always has been a matter of consumer demand. None of the numerous advantages of fiber optics has been sufficient to justify deployment as the primary means of reaching all customers.

Let me reiterate the advantages and disadvantages of fiber optics. The advantages of using fiber optics include:

- *Nonsusceptibility to electromagnetic interference.* Glass is a nonferrous/nonmagnetic material.
- *Elimination of ground returns.* All electrical systems need to be grounded. Grounding establishes a difference in electrical potential between electrical conductors. Light does not need to be grounded.
- *Small size.* One strand of fiber (the diameter of a human hair) can carry data at speeds in excess of 100 gigabits per second. Given this small size, carriers can lay fiber where laying (underground) metallic cable becomes obtrusive for environmental reasons, property access issues, or limited room in existing underground communication cable conduit.
- *Light weight.* Not counting the protective insulation, a fiber strand is as light as a human hair.
- *Little maintenance is required.*
- *Glass does not age as fast as metal.*
- *Support for incredibly low bit error rates, as low as* 10^{-16}.
- *Cost effectiveness for high traffic needs.* Even though the cost per foot is dropping to approach to the cost of copper (about $0.10 US) the fact is that one must look at each specific situation. This will be discussed in detail later.

Fiber optics' disadvantages are few in number:

- *It is expensive for low traffic load needs.* The cost per foot for fiber is about 40 percent higher than the cost per foot of copper, so the business case to deploy fiber optics to the home does not exist yet. However, the need to create networks to meet the perceived demand for Internet access in the very near term is driving down the cost of fiber.
- *It requires special electronics for the light source, light detection system, encoders, and decoders.* This requires special skill sets beyond simple hook up and cable splicing.
- *It is susceptible to signal attenuation (loss).* However, in comparison to metallic T-1, in which repeaters need to be installed at 1,000-foot intervals, fiber optic systems can operate with repeater distance intervals of up to 100 miles.

We have seen that the Internet is the primary driver for the deployment of fiber in geographic areas where there are no easily identifiable customers. Before the appearance of the Internet, carriers deployed fiber on their own in order to manage long distance network costs and to address data needs in heavily conduit-congested markets. As I noted in *M-Commerce Crash Course* the woes of the Internet space are temporary. Communities and carriers are deploying thousands of miles of fiber optic cable in order to position themselves for the much-anticipated explosive growth of the Internet business space. To wait for the demand to appear would be a death knell for any service provider because by the time the demand showed up in large enough quantities a competitor could easily take away all the business. The need to position networks for future growth has driven carriers to deploy large fiber optic rings in anticipation of business.

We will soon see fiber to the home (FTTH) making its appearance in the marketplace. Although FTTH is a concept dating back to the early 1980s, it has never been cost justified. The Internet will drive FTTH as well as any other transmission technology that brings more bandwidth to the home. The Internet will wither away and disappear unless more bandwidth is delivered to all consumer markets.

Next, we will explore the kinds of multiplexing formats that have been able to mine capacity out of the fiber optic transmission facility. These formats are serving as the drivers behind the growing value of fiber optics and the need for more bandwidth.

OPTICAL TRANSMISSION FORMATS

Fiber optics presented a challenge to transmission engineers. The European and North American digital hierarchical transmission formats only supported transmission speeds up to E-3 and DS-3 respectively. The European Telecommunications Standards Institute (ETSI) digital hierarchy is shown in Table 3.1.

TABLE 3.1 European Digital Hierarchy

DIGITAL SIGNAL LEVEL	BANDWIDTH	NUMBER OF VOICE CHANNELS
DS-0	64 kbps	1
E-1	2.048 Mbps	30
E-2	8.448 Mbps	120
E-3	34.368 Mbps	480
E-4	139.264 Mbps	1920
E-5	565.148 Mbps	7680

North America's multiplexing scheme is different. The reasons why different areas of the planet are using different formats is an issue of debate and not important for this book. The North American digital hierarchy is shown below in Table 3.2.

TABLE 3.2 North American Digital Hierarchy

DIGITAL SIGNAL LEVEL	BANDWIDTH	NUMBER OF VOICE CHANNELS
DS-0	64 kbps	1
DS-1	1.544 Mbps	24
DS-2	6.312 Mbps	96
DS-3	44.736 Mbps	672
DS-4	274.176 Mbps	4032
DS-5	564.992 Mbps	8828

In the 1980s those wishing to use DS3 or E-3 rates were entering the realm of proprietary multiplexing schemes. To the commercial marketplace, proprietary multiplexing schemes meant suffering for the commercial market. If proprietary schemes were allowed to dominate the transmission marketplace, then the entire transmission business would suffer. Interoperability is important to service providers and network owners because without standardized equipment and network interfaces, the cost of running a network would be astronomical.

In the early 1980s, the perception was that fiber was the answer to all telecommunications transmission issues. However, after a few years, carriers realized that the business case to support a massive rollout of fiber did not exist and could not be written. By the time the carrier community had realized that market demand was not that great, there was a plethora of transmission equipment in the marketplace and none of it was interoperable. Fortunately, the global telecommunications industry recognized the need to create standards before it was too late, before the marketplace became flooded with so much equipment that none of the industry manufacturers or carriers would or could support industry standardization of fiber optic transmission equipment without losing hundreds of millions of dollars of equipment.

Industry standardization led to the creation of two standard optical formats, one for Europe and other continents and one for North America. North America's optical standard is SONET. The rest of the world supports the optical format known as Synchronous Digital Hierarchy (SDH). The following sections describe SONET and SDH.

SYNCHRONOUS OPTICAL NETWORK (SONET)

SONET was developed by Bellcore (now known as Telcordia) and the American National Standards Institute (ANSI). SONET is a high-speed transmission protocol format that defines the features and functionality of an optic transmission system based on synchronous multiplexing. It is much more than just a "souped up" DS-4 level (and higher) bit rate format. SONET is an optical format capable of supporting speeds ranging from 150 Mbps to several gigabits per second. SONET was designed to address both network access by customer premise equipment and network interconnection between providers at very high speeds. From an OSI model perspective, SONET is a Layer 1 protocol, physical-layer signaling. SONET enables an optical transmission system to transport multiple signals from multiple sources and at different capacities.

Early in the deployment of DS-4 optical equipment, manufacturers used a variety of multiplexing arrangements that did not maintain intact the basic DS-0 signal. When you look at a DS-1 bit stream, the signal is carrying information at a rate of 1.544 Mbps with a relative error of ± 150 pulses per second. A

DS-3 bit stream is carrying information at a rate of 44.736 Mbps with a relative error of +1789 pulses per second. We now face a situation where it is possible to carry information at multiple rates; it is not easy to discern the individual streams. The bit streams, whether they are multiples of DS-1 or a combination of DS-1 and DS-3, have such wide and varying relative error ranges that you can confuse streams with one another. (Note that there was a DS-2 and even a DS-1C rate, but that the DS-1C and DS-2 rates were not commercially popular.) Furthermore, techniques existed that enabled vendors to interleave the bit rates (cost effectively) to create a DS-2 and DS-1C. To demultiplex the information was a simple task. Therefore the focus of SONET was on supporting rates at DS-3 and higher. SONET is a time division multiplexing schema.

Lack of synchronization within a vendor's specific multiplexing arrangements caused the system to have data-transmission efficiency problems. Without the basic signal, DS-0, kept intact, it was more difficult to maintain and interconnect with different networks, filled with equipment from different manufacturers. SONET (and SDH) changed this scenario. In fact, prior to SONET, operating networks were not really in synchronization with each other. At high speeds, the lack of multinetwork synchronization magnified the problems encountered with data interpretation.

Unlike T-1, DS-1, DS-2, and DS-3 formats (or even ETSI based E1, E2, or E3), which support multiple signaling formats defined "after the fact," SONET is a format in and of itself. SONET was designed specifically to take advantage of the full potential bandwidth of "glass." SONET is a transport protocol as opposed to a network control signaling protocol like Signaling System 7 (SS7) or Asynchronous Transfer Mode (ATM).

A significant portion of the SONET signal structure (frame structures) is dedicated to network management and network maintenance. A SONET frame is 810 octets (bytes) in size.

SONET was designed with supporting existing signaling formats in mind. It has the capability and flexibility to support customer services and network signaling formats (such as ATM, ISDN, X.25, and SS7).

As the previous section implied, optical data rates start at rates higher than DS-3:

- OC-1 equates to a data speed of 51.840 Mbps
- OC-3 equates to a data speed of 155.520 Mbps
- OC-12 equates to a data speed of 622.08 Mbps
- OC-48 equates to a data speed of 2488.32 Mbps
- OC-192 equates to a data speed of 9953.28 Mbps

The SONET rates are defined as synchronous transport signal (STS) levels. The OC rates match the STS rates exactly. The STS rates are measured in electrical terms as opposed to being measured in optical terms. One is a representation of information in electrical impulse and the other represents the equivalent impulses of information in terms of photons. See Table 3.3 for commercially popular rates.

TABLE 3.3 Commercially Popular Rates

ELECTRICAL SIGNAL	OPTICAL SIGNAL	DATA RATE
STS-1	OC-1	51.84 Mbps
STS-3	OC-3	155.520 Mbps
STS-9	OC-9	466.56 Mbps
STS-12	OC-12	622.08 Mbps
STS-18	OC-18	933.12 Mbps
STS-24	OC-24	1.244 Gbps
STS-36	OC-36	1.866 Gbps
STS-48	OC-48	2.488 Gbps
STS-192	OC-192	9.953 Gbps
STS-768	OC-768	40 Gbps

Note that the OC-n transmission rates can be directly related to basic voice capacity via the 64 kbps basic transmission speed.

As with any transport protocol, the basic bit frame is formatted around the basic rate; in the case of SONET it is the STS-1 rate of 51.84 Mbps. Outside North America another format was created to support synchronization needs for telecommunications service providers, this was SDH.

SYNCHRONOUS DIGITAL HIERARCHY (SDH)

The SDH format was created for the same reasons SONET had been created in North America: to support a cost-effective and technically effective way of supporting high-speed optical data transmission. Like SONET, SDH is a time division multiplexing schema. However, the differences between SONET and SDH are significant.

SDH frames are larger than SONET frames and therefore capable of carrying more information in a single package (or payload). The digital rates for Europe appear in Table 3.4.

TABLE 3.4 European Digital Hierarchy Rates

HIERARCHICAL LEVEL (E-N)	EUROPEAN RATE
E-0	64 Kbps
E-1	2.048 Mbps
E-2	8.448 Mbps
E-3	34.368 Mbps
E-4	139.264 Mbps
E-5	565.148 Mbps

Whereas SONET defines synchronous optical rates in terms of STS-n, SDH defines the optical rates in terms of STM-n. Table 3.5 illustrates the optical rates supported in the SDH hierarchy.

TABLE 3.5 SDH Hierarchy Rates

ELECTRICAL SIGNAL	OPTICAL SIGNAL	DATA RATE
STM-0	OC-1	51.84 Mbps
STM-1	OC-3	155.520 Mbps
STM-3	OC-9	466.56 Mbps
STM-4	OC-12	622.08 Mbps
STM-6	OC-18	933.12 Mbps
STM-8	OC-24	1.244 Gbps
STM-12	OC-36	1.866 Gbps
STS- 16	OC-48	2.488 Gbps
STM-64	OC-192	9.953 Gbps
STM-256	OC-768	39.813 Gbps

SDH was designed to be a superset of optical rates; in other words, to support SONET formatted signals. The SDH basic frame format (STM-1) supports a larger payload than the SONET frame.

The SDH frame (STM-1) is 2,430 octets (bytes) in size, which is several times larger than the 810-octet SONET frame (STS-1).

SDH AND SONET: IN PERSPECTIVE

SDH and SONET represented a major advancement in the way transmission system could support large bandwidths of data. It took several years for both standards to be completed. During the development of the respective standards fiber optic rings and strands were deployed. As fiber was deployed, SONET and SDH were used when necessary. Unlike many technological innovations, the commercial rollout of fiber did not occur faster than the standards could keep pace with. In the case of SDH and SONET, the pace of commercial fiber deployment was at a fairly reasonable rate, so that there was not a huge amount of unused inventory in the field.

In global fiber deployment, both the market demand and the available bandwidth tracked one another. The lack of market initiatives to deploy fiber to the home and small to medium sized business actually prevented fiber from finding "the killer app" needed to trigger an explosive growth. During the early 1980s there were exploratory efforts to bring fiber to the home (also known as fiber to the curb). However, these efforts failed to find business community support. The cost of changing existing wireline capital, which could still meet consumer needs, was too high for the wireline telephone companies. This was before the Internet; the whole concept of data to the home or to small- and medium-sized business was not clearly understood.

The advent of the Internet and other multimedia business opportunities created a demand for more bandwidth. The bandwidth provided by copper is limited, but fiber optics provides more bandwidth capacity. Unfortunately, in the late 1990s, industry discovered that SONET and SDH could not support data speeds beyond 9.953 Gbps. Furthermore, the business customer base was now seeking the flexibility to use the optical bandwidth for a variety of multimedia applications: video, Internet video games, music, music videos, high-resolution computer generated animation, and even interactive customer transaction screens. The telecommunications industry responded with Wave Division Multiplexing (WDM).

SONET and SDH are protocols that can ride on top of the WDM schema. WDM enhanced fiber optics transmission as described below. Ethernet is emerging as a potential networking alternative to SONET and SDH. A great deal of work has been done in the last few years to enhance Ethernet from its original 3 Mbps transmission speeds to the current 10 Mbps and 100 Mbps corporate Intranet speeds and even further to Gigabit speeds. The technology is known as Gigabit Ethernet. The concept of Gigabit Ethernet is about extending the power of the current corporate Intranet technology out into a wider environment. SONET and SDH are optical standards while Gigabit Ethernet is a data (electrically based) standard. SONET, SDH, and Gigabit Ethernet transmission can all be made using WDM.

WAVE DIVISION MULTIPLEXING (WDM)

Prior to WDM, fiber optical transmission systems used a single beam of light. WDM took the approach of using more than one light beam, simultaneously. WDM is a combined Frequency Division Multiplexing (FDM) and Time Division Multiplexing (TDM) schema.

Frequency division multiplexing takes a bandwidth of spectra and slices it up for use via frequency bands. When light is divided via FDM the various streams of separated light are different colors. Light at different frequencies can be discerned by the color of the light. The original fiber optic transmission systems used a red light for transmission from the point of origin and blue light from the opposite or receiving end. In WDM, different colors (wavelengths) of light carry different types of information down the same fiber pipe and origination point. At this point WDM's TDM capabilities are used to combine the wavelengths of light for transmission to the receiving end. The wavelengths of light are then separated using a diffraction grating device to separate the wavelengths of light. See Figure 3.13 for an illustration of the WDM concept.

Network providers ensure that the various colors of light and frequency separated by about 200 GHz. This channel spacing separation is used to mitigate the adverse effects of transmission nonlinearities and attentuations. Conceptually, WDM should be able to deploy multiple laser sources using add–drop multiplexers (ADMs) to selectively pick up and drop off wavelengths where needed.

When channel spacing became tighter, at no more than 50 GHz, WDM became known as dense WDM (DWDM). A DWDM system uses multiple light sources (lasers) just as a WDM system does, however, more wavelengths of light can be packed into the fiber strand. Each light source is operating at a specific frequency; today up to 16 lasers can be used as input into a DWDM. Figure 3.14 is an illustration of a DWDM system. Note that all this assumes the use of single mode fiber, which is the most widely deployed type of fiber.

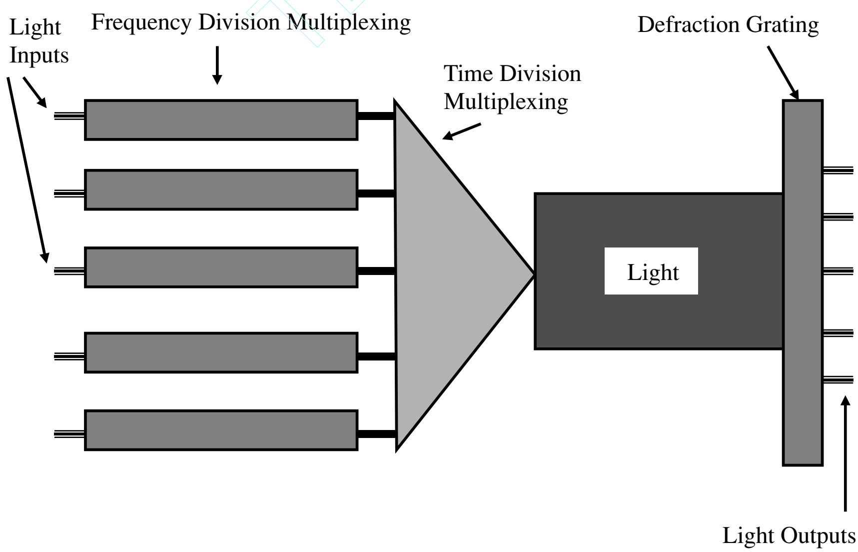


FIGURE 3.13 Wave Division Multiplexing (WDM)

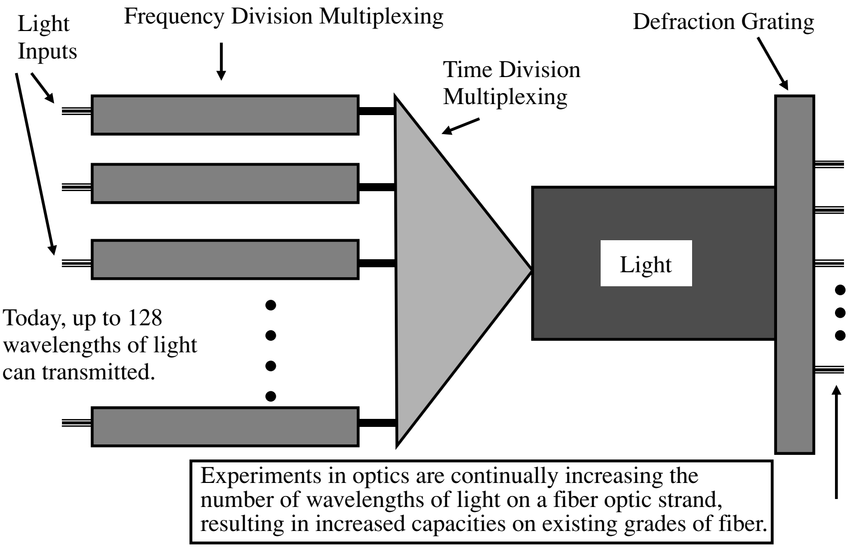


FIGURE 3.14 Dense Wave Division Multiplexing (DWDM)

WDM/DWDM CAPACITIES

Aside from channel spacing, a WDM/DWDM system conceptually supports the use of multiple wavelengths of light on a single fiber. As an example, let's take an OC-48 fiber strand. The OC-48 fiber rate is 2.488 Gbps. Using DWDM technology, the development community first demonstrated the use of two wavelengths of light. This resulted in an increase in transmission rate capacity (throughput) to 4.976 Gbps (for the sake of simplicity we shall call this 5 Gbps). By adding more wavelengths of light we can increase the throughput capacity of the fiber.

DWDM rates start at 2.5 Gbps. In other words, DWDM had no financial value until the transmission community began to transmit above the 2.5 Gbps rate. When OC-192 was first introduced, DWDM had not reached the commercial marketplace. Today there is OC-768 with speeds of 39.813 Gbps. The fact is that with improved TDM systems and higher-grade (clarity and fewer imperfections) fiber, the industry has been able to forestall the use of DWDM systems. However improvements in fiber grade and TDM systems will only take one so far; the economics of simply adding additional wavelengths of light make DWDM undeniably the best path to follow.

Table 3.6 summarizes the DWDM rates and the associated normal optical rates. Note that the non-DWDM version of the OC-48 rate is 2.5 Gbps and the OC-192 rate is 10 Gbps. The following table is written in multiples of OC-48 and OC-192 equivalent rates.

TABLE 3.6 DWDM Rates and the Associated Normal Optical Rates

DWDM	Number of Wavelengths (λ)	Number of OC-48	Number of OC-192	Throughput
1	1	1		2.5 Gbps
1	2	2		5 Gbps
2	4	4		10 Gbps
3	8	8	2	20 Gbps
4	Hybrid of OC-48 and OC-192	1	2	25 Gbps
5	16	16		40 Gbps
6	Hybrid of OC-48 and OC-192	4	4	50 Gbps
7	Hybrid of OC-48 and OC-192	32	8	80 Gbps
8	16	12	4	100 Gbps
9	16		16	160 Gbps
10	Hybrid of OC-48 and OC-192	16	16	200 Gbps

The DWDM rates are described in terms of multiples of OC-48 and OC-192. These descriptions are used as the basis for selling and packaging the bandwidth in a standard format for the customer.

DWDM systems currently support up to 16 different wavelengths. It is projected that in a few years we will be seeing up to 128 wavelengths of light over a DWDM system. From a cost–benefit perspective, the telecommunications industry is optimizing and extending the usefulness of fiber in the telecommunications marketplace. DWDM combines the strengths of TDM and FDM. As you can see from Figure 3.15, the various light sources are focused into a multiplexer which then combines all the different frequencies into different time

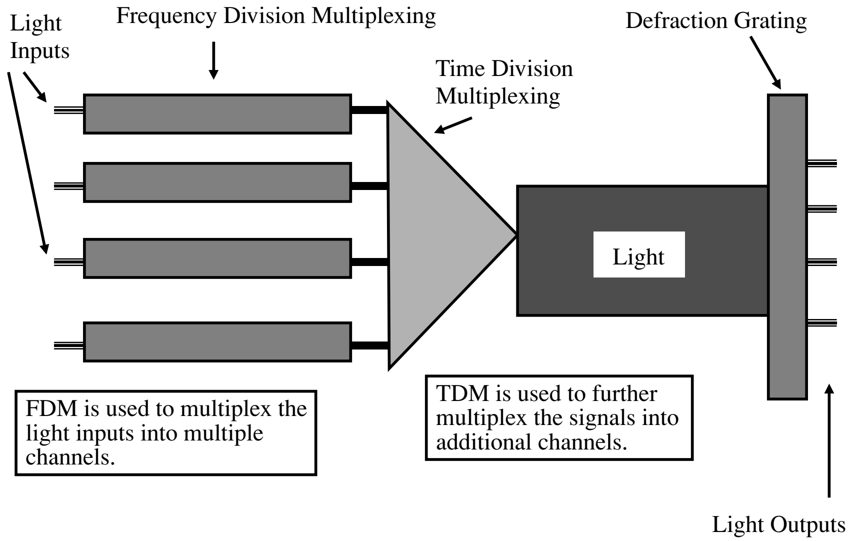


FIGURE 3.15 TDM and FDM Roles in WDM Transmission

slots. The combined (and transmitted) light is separated out into the original wavelengths of light at the receiving end by a diffraction device.

WDM systems are currently capable of supporting data rates up to 400 Gbps, and additional wavelengths are being added. It is anticipated that by the end of 2002 we will see speeds up 3.2 terabits per second (Tbps). By the end of 2004, it is expected that we will see up to 160 wavelengths of light being supported, which equates to 16 Tbps. This assumes the industry is using current OC-192 fiber quality grades. There will be more discussion later on fiber quality, cost of fiber, cost of labor, and their relationship with one another.

FREE-SPACE OPTICS

I define free-space optics as laser light. In the 1960s and 1970s, the telecommunications industry "toyed" with lasers for telecommunications. Governments have long used lasers for military communications, but the commercial telecommunications industry used lasers only in a very few instances where installation of cable was both costly and physically prohibitive. The challenges faced by laser communications include:

- Light (signal) dispersion due to high particulate matter in the atmosphere (i.e., pollution).
- Atmospheric changes (i.e., weather) that could cause signal dispersion. These changes include rain and humidity.
- Laser light telecommunications is line-of-sight communications, which means that one is limited to a transmission distance of about 30 miles, assuming a tower about 100 meters high. One factor affecting line of sight is curvature of the earth.
- Manmade objects, such as buildings and other obstacles, can affect line-of-sight communications.
- Airport flight paths may intercept light signals.

Figure 3.16 is an illustration of free-space optics.

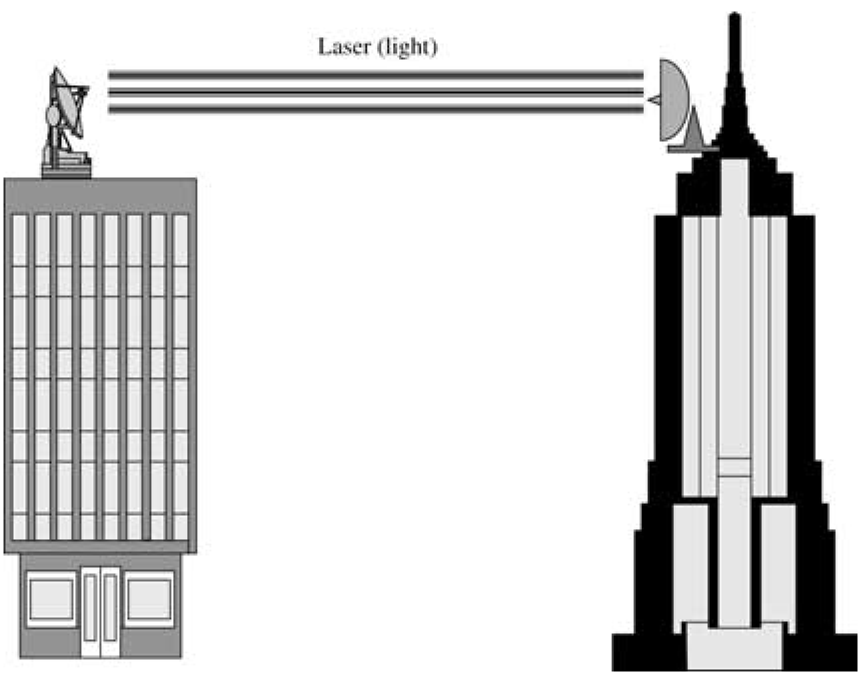


FIGURE 3.16 Free-space Optics (the Laser)

From the 1960s through the 1980s, the cost of a laser unit was too high to make it viable for commercial telecommunications. However, the cost of the laser has dropped significantly, and the quality of the laser units has risen dramatically.

I believe that free-space or fiberless optics will play an important role in the future of telecommunications. Specifically, the local loop will become the next area of open business warfare between the carriers. This topic will be investigated in more detail later in the book.

IMPLEMENTATION ISSUES

We could assume that with all of the benefits of using fiber or even free-space optics the marketplace ought to be using this technology in a widespread fashion. However, we must consider certain real-world issues. Among those issues is the current marketplace and who dominates the telecommunications business landscape. As much as the technical purists may wish to ignore business issues, the reality is that they cannot and should not be discounted. Remember three things: things cost money, things take time to execute, and time is money.

Fiber deployment on a nationwide basis for the long distance network is economically feasible and has already been executed, because cost justifications could be made. However, the local loop has yet to see any serious penetration of fiber. The fiber optics deployed in many markets cannot compare to the amount of copper in the street; the reality is that the local loop is the last bastion of copper. No business case has been written to support the deployment of fiber to the home.

Fiber to the home, now popularly known as Fiber to the Curb (FTTC), refers to the mass installation of fiber optics to the curbs near homes and businesses. In the 1980s, the vision of FTTC was one of bringing massive volumes of data to the user. The problem was that there were no data services requiring rates in the megabits per second range. The services then sold were carried over switched 56 kbps lines and ISDN. Neither ISDN nor switched 56 kbps service was ever really successful, and both were provided over basic twisted-pair wires. FTTC was supposed to bring massive bandwidth to the doorstep of the user; unfortunately, there were no compelling services to get users to cover the cost of the 56-kbps services provided by ISDN, so no telecommunications professional could justify the cost of fiber.

The business case for fiber only works in the long distance network where the volume of traffic is aggregated over selected facility routes. In other words, the cost effectiveness to carry large volumes of data over long distance using fiber can be supported.

In order to penetrate the local loop with fiber customer' demand and a willingness to pay for data services must be high. Further, there must be enough customers who want to pay for such services. This boils down to a few basic points. First, there must be services that users will want to purchase. Second, the users must be willing to pay for the services. Third, there must be a large enough group of users to pay for the services. Fourth, the profit margins must be large enough for a carrier to want to provide the service. Figure 3.17 sums up these points. The

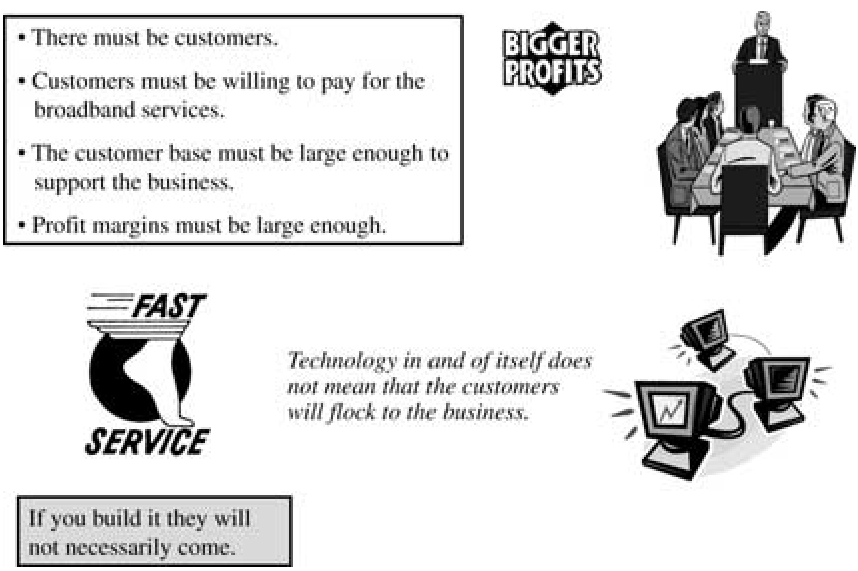


FIGURE 3.17 Implementation Issues

fact that fiber optic costs are rapidly decreasing and approaching the cost of copper is not relevant. By the time this book is published the cost of fiber may be less than that of copper. The reality is that it takes human resources (labor) to install fiber. The cost of labor will not drop any time soon.

SUMMARY

Fiber optic technology will eventually find its way to the curb because it offers one way of bringing large bandwidth to the user. Over the years fiber optical transmission has improved to the point at which a terabit-per-second rate can be supported. Fiber has so many advantages that it would be unwise for the telecommunications industry to stop efforts to bring fiber to the curb. The advantages of fiber optics are:

- Nonsusceptibility to electromagnetic interference. Glass is a nonferrous/nonmagnetic material.
- Elimination of ground returns.
- Small size.
- High tensile strength.
- Light weight—not counting the protective insulation, a fiber strand is as light as a human hair.
- Low maintenance requirements.
- Slower degradation rates than metal.
- Support for incredibly low bit error rates, as low as 10^{-16}.
- Cost effectiveness for high traffic needs.

The advantages of fiber outweigh its disadvantages. The challenge for fiber optic supporters is finding the business case to support the deployment to the home and every business. I believe this business case is developing now, and that it is only a matter of time before the business issues surrounding FTTC are resolved.

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CHAPTER FOUR

METALLIC BROADBAND TECHNOLOGIES

In an age when industry chatter is filled with talk about fiber optics and wireless technologies, it may seem odd to see anything written about transmission technologies that use metal. The fact is that the bulk of transmission facilities in place are copper and in the local loop. Copper transmission systems have been in place since 1876, wereas fiber optics and wireless broadband are only a recent phenomena. Metallic transmission systems are limited by the bandwidth they can support, but attempts have been made since the 1980s to extend the useful commercial life of metallic transmission systems. This chapter will not readdress basic T-n transmission technologies. Enough has been said of the various metallic network transmission facilities that connect networks.

Instead, this chapter focuses on the metallic transmission facilities that connect the network to the subscriber. The bulk of the "copper in the street" is in the local loop. The first thing to focus on is gaining an understanding of the local loop.

LOCAL LOOP

The local loop is the portion of the physical telecommunications circuit between the LEC's central office (local switch, also known as a Class 5 switch) and the customer's premise. This circuit was originally twisted-pair conductors, essentially a continuous loop of wire. The original local loop was solid metal (copper) wire. Despite the deployment of digital and high-speed access systems in the home and the customer premise, the majority of the wiring to the customer premise is still largely twisted-pair. See Figure 4.1.

The piece of the network that connects the local telephone company to the long distance telephone company is not part of the local loop. The local loop is the piece of the network that connects the local telephone company to the user.

Despite what the Telecommunications Act of 1996 brought to the industry, the greatest challenge for the Competitive Local Exchange Carriers (CLECs) has been penetrating the local loop. To some, penetrating the local loop requires installing wire to the premise or owning and maintaining the existing local wire. If a CLEC were to install its own local loop,

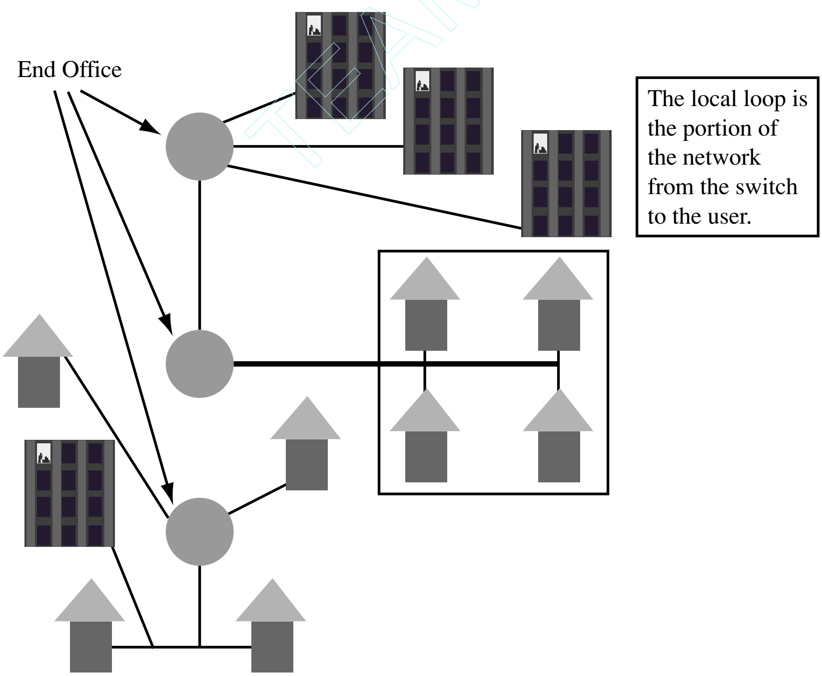

FIGURE 4.1 Local Loop

it would make expenditures on a scale far beyond the basic switching systems, in volumes of equipment and labor. The costs are crippling. Figure 4.2 is a representation of the CLEC and some of the challenges it faces.

To many CLECs, penetrating the loop did not necessarily mean owning and maintaining the physical outside plant but meant "owning the customer," as the primary provider of basic voice and data telecommunications. However, the Telecommunications Act of 1996 and current state tariffs and regulations require the ILEC (Incumbent Local Exchange Carrier) to continue maintaining the "wire" in and around the neighborhoods and communities, charging for regulated fixed fees and surcharges, which the CLEC can charge back to the subscriber. This is how many CLECs rightfully claimed that they are using telco wire. Unfortunately, most CLECs have been unable to face the challenge of creating profit margins in a business that requires huge capital and labor expenditures.

Most CLECs are resellers of ILEC services and systems, to some degree or another. CLECs may own and operate their own switches and building facilities. CLECs may own some of their own transmission facilities. CLECs may even obtain all the backbone facilities (interswitch and intranetwork connectivity) from a party that is not an ILEC; this has occurred in

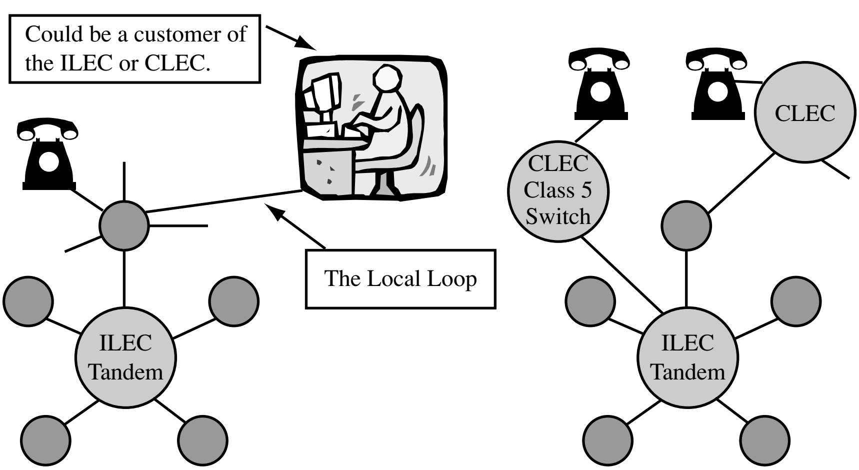

FIGURE 4.2 CLEC Challenges

very few cases. However, the CLEC has always had to work with the ILEC for local loop access. Given the critical nature of timely deployment to provide service to subscribers, the CLEC needs to find ways to create margin on its books, in all facets of its business, including the local loop. This results in the CLEC's doing everything but controlling its own customer accounts.

Control of the local loop means control of the customer account. No one really controls the customer; however, the ability to control the wire to the home and business premise means controlling how the account is served. When a customer loses service, and the service trouble appears to be on the wire to the subscriber, the local exchange carrier used by the subscriber is responsible for tracking down the problem. The CLEC usually calls the ILEC for assistance. The ILEC performs this service for the CLEC for a fee. Needless to say, many ILECs give CLEC issues low priority; some CLEC customers could sit without service for days, resulting in angry customers who eventually ended dropping CLEC service and returning to ILEC service. Figure 4.3 is an illustration of the customer relationship involving the CLEC and the ILEC.

Note that despite the 2000 and 2001 downturn in the markets, competitive telecommunications is not dead and the CLECs will reappear.

DIGITAL SUBSCRIBER LINE TECHNOLOGIES: XDSL

To find ways of penetrating the local loop to control the "last mile" to the user, some CLECs deployed xDSL (x-Digital Subscriber Line) technology. This technology was viewed as a way of entering the home and business on a more cost-effective basis. The letter "x" in front of the term "DSL" represents a generic labeling for the family of DSL technologies. The "last mile" is another term used to address the local loop.

DSL is a loop transmission technology developed by the wireline local exchange carriers (LECs) to optimize the "last

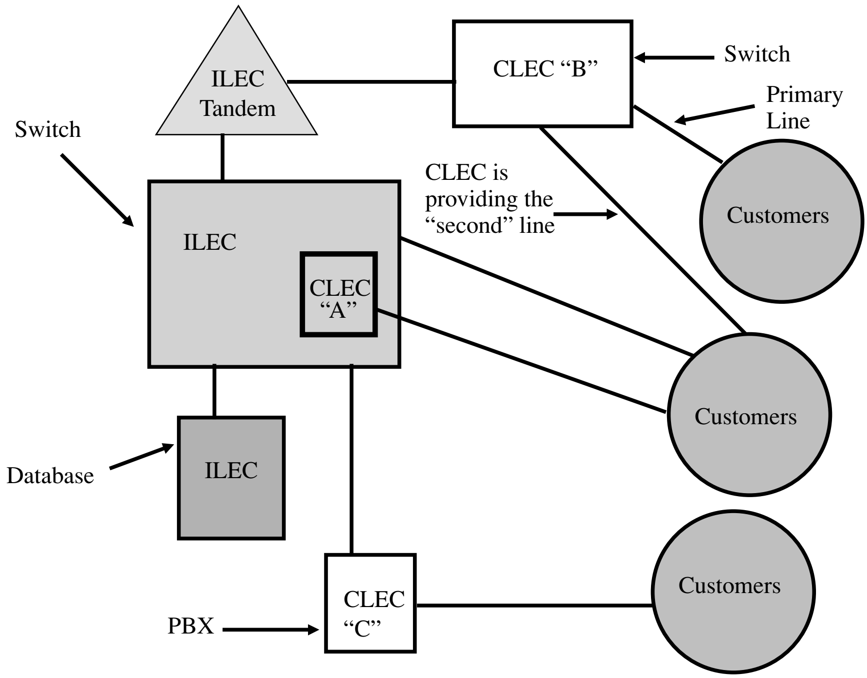

FIGURE 4.3 The Customer, the CLEC, and the ILEC

mile" to the home or small- to medium-size business. The optimization of the last mile is in actuality the ability to provision wideband multimedia video and data services to the home over twisted-pair wires. Layer 1 and higher network signaling protocols and technologies like SS7, ATM, and intelligent network triggers enhance the way networks as a whole functioned, enabling the provisioning of new types of services. Essentially, xDSL technology is a LEC's way of getting more "mileage" out of the existing twisted pair or getting "more for the money invested."

REASONS FOR xDSL

xDSL technologies enable a carrier to optimize the use of its own local loop or a CLEC's use of the local loop. Much of the modernization of the network or network of networks has taken place from a network-to-network and switch-to-switch perspective; such as, backbone network signaling for large-scale, regional, and national networks. However, there have been few, if any, significant enhancements for the local loop.

When the loop was first constructed by the ILECs, it was designed to carry only voice conversations. The human voice operates in the 300–3,400-Hz range, and the loop was designed to carry information (the human voice) at frequencies from 300 to 3,300 Hz. This narrow frequency band of operation allows modems to function quite well over twisted-pair wire; however, modems can transmit (with a high level of data integrity) at speeds up to 57,600 bps. Higher data transmission speeds result in either noise or useless received data. Given the history of the loop and 125 years of embedded outside plant, the question is: How do you bring T1/DS1 and higher-grade services to the home and small- and medium-size business without changing the loop? The ILECs were the first to examine this question, only to face the following facts:

- Embedded plant on the order of millions of miles for a single ILEC would have to be replaced.
- Labor costs associated with such a changeout were staggering.
- There was no compelling business case to make such an investment in new equipment; the existing twisted pair is sufficient even for Internet dial-up.

The ILECs understood that it would take time and money to make such an investment, but in the 1980s it was not clear whether or not there was a business case to do so. During the 1980s, the ILECs were exploring a number of ways to reduce outside plant costs and position themselves for next generation services.

Fiber optic deployment was one of the avenues explored by the ILECs. There had been attempts to bring fiber to the curb (FTTC), to the home (FTTH), to the neighborhood (FTTN), around the town (FATT), and around the county (FATC). The installation of fiber directly to a home would mean that the LEC had a wideband information pipe directly to the wall jacks in the home. Discussion of signaling protocol wasn't even a priority issue at the time these efforts were being executed 15 years ago. The goal was to get bandwidth into the home or small- or medium-size business because there was a fear that cable television would provide voice, video, and data services using its coaxial cable transmission systems. xDSL was one of the technologies explored for deployment to meet the competitive challenge. Fortunately for the ILECs, cable television deregulation came in time (1992) to cause many cable TV systems to enter bankruptcy. With competition disappearing, the overwhelming need to deploy bandwidth to the home in an expeditious manner disappeared. Therefore, to some extent, the ILECs' drive to develop xDSL technologies also disappeared. Figure 4.4 is an illustration of the drive to increase bandwidth.

Between 1996 and 2000, xDSL became very popular because of the Telecommunications Act of 1996 and the result-

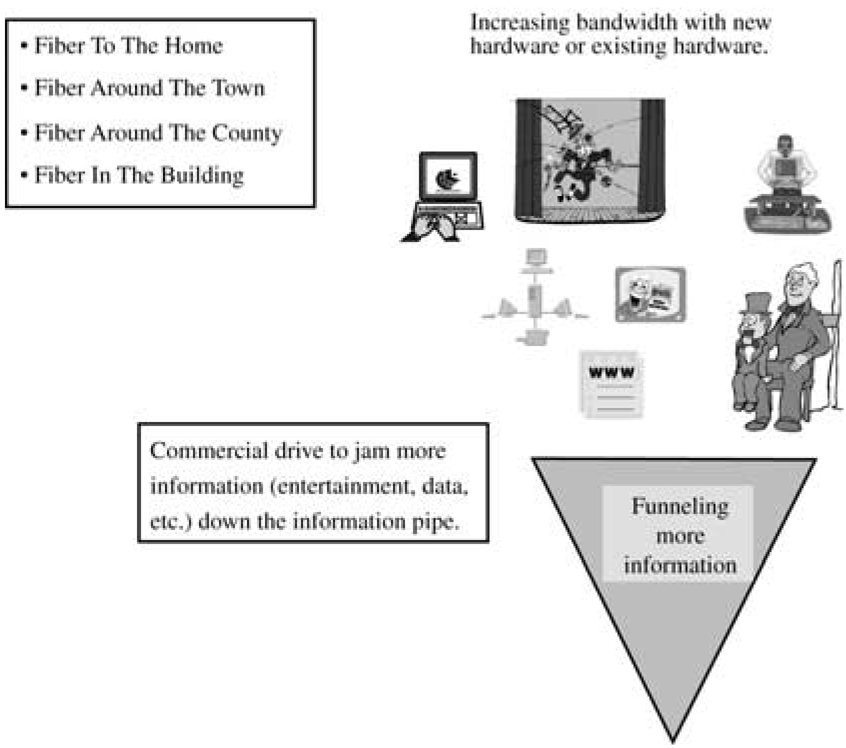

FIGURE 4.4 Increasing Bandwidth—Early Attempts

ing growing competition from the CLEC community. Because CLECs are pushing xDSL deployment, the ILECs became interested in xDSL after the CLECs began to deploy it as a means of bringing bandwidth to the user without the involvement of the ILECs (their competitors).

The ILECs saw their creation being used against themselves; they did not want to sit idly by and watch the CLECs use this technology to gain a foothold in the marketplace. This competitive environment was beneficial to digital subscriber line technologies development.

DEPLOYING xDSL

The first step in understanding xDSL is to understand the physical limitations of twisted-pair wire. Twisted-pair cannot carry high frequency transmissions. A simple solution would be to install larger gauge wire. However, larger gauge wire is more expensive and results in higher per-meter (or foot) outside plant costs. To replace the existing twisted-pair wire would be unrealistic; however if past experience is any measure of what can occur, twisted-pair will be around for several years (maybe even decades) and technologies like xDSL will coexist with fiber.

Transmitting high-speed data over twisted-pair presents some challenges. The transmission properties of twisted-pair wire (bundled in a multipair bundle of wire) are affected by wire gauge, type of insulation, and twist lengths.

Twisted-pair wire is typically either 26 or 24 AWG (American Wire Gauge); this is very thin wire. Metallic wire is like any other medium: It attenuates energy. The insulation may serve as a dielectric medium, thereby resulting in a capacitive effect. The twisting of wire can create an inductive effect. High-frequency signals are used to support high-speed data transmissions. At a given power level, the high frequencies travel a specific distance over a given diameter of wire. At the same power level but at lower frequencies, the signal will travel further. In other words, high-frequency energy will dissipate faster than lower frequency signals. Increasing the gauge of the wire means a larger diameter wire and results in lower electromagnetic resistance. This is too expensive to consider. Figure 4.5 illustrates wire gauge issues.

COMPONENTS OF xDSL

There are various forms of DSL technology, and each version can be characterized in the same manner. Since xDSL is a transport and access technology it is completely neutral as it relates to signaling protocols. xDSL employs the following generic system components:

- Signal splitters.
- Customer premise modems (specific to each type of DSL) to multiplex and demultiplex the channels over the twisted pair. These modems are essential to providing xDSL services to a home or business.
- Transceiver units at the service provider's switching facility.
- Transceiver units at the subscriber's end.

Figure 4.6 illustrates this general configuration.

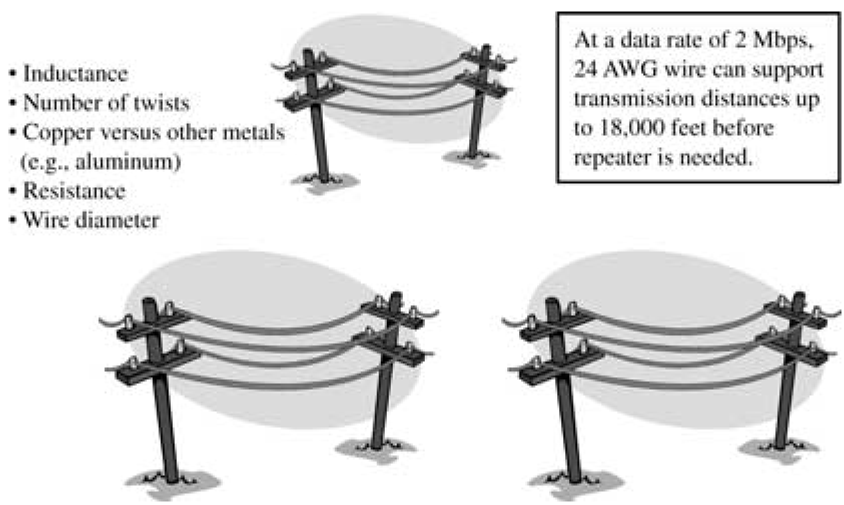

FIGURE 4.5 Wire Gauge Issues

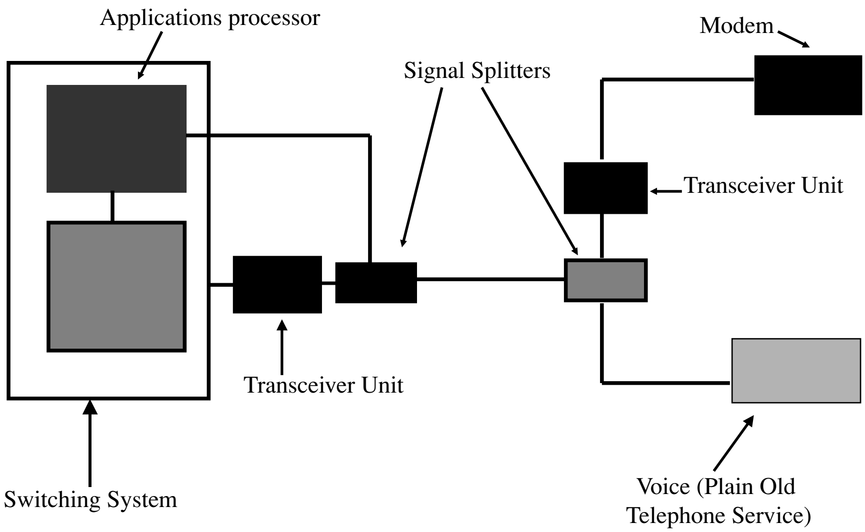

FIGURE 4.6 xDSL

Signal splitters are devices that divide or split a xDSL signal into voice and data channels so that voice and data signals are traveling at different rates. The splitter resides at the customer premise.

The customer premise modem, also known as the xDSL modem is a special type of modem designed to multiplex and demultiplex the voice and data signals. The modems are located at the customer's location. The carrier must provide an equivalent at its own end.

Carriers use digital subscriber line access modules (DSLAMs) to hold several xDSL modems. DSLAMs also serve as a way for a carrier to concentrate xDSL customers onto its backbone network for network-to-network connectivity. Figure 4.7 is an illustration of the DSLAM's role in the xDSL network configuration.

Transceiver units are integrated into the modems and serve as the transmission and receiver components of the modems. The units are typically designated as transceiver unit R (for remote; customer location) or C (for central office–based).

Figure 4.8 is an illustration of the xDSL network configuration.

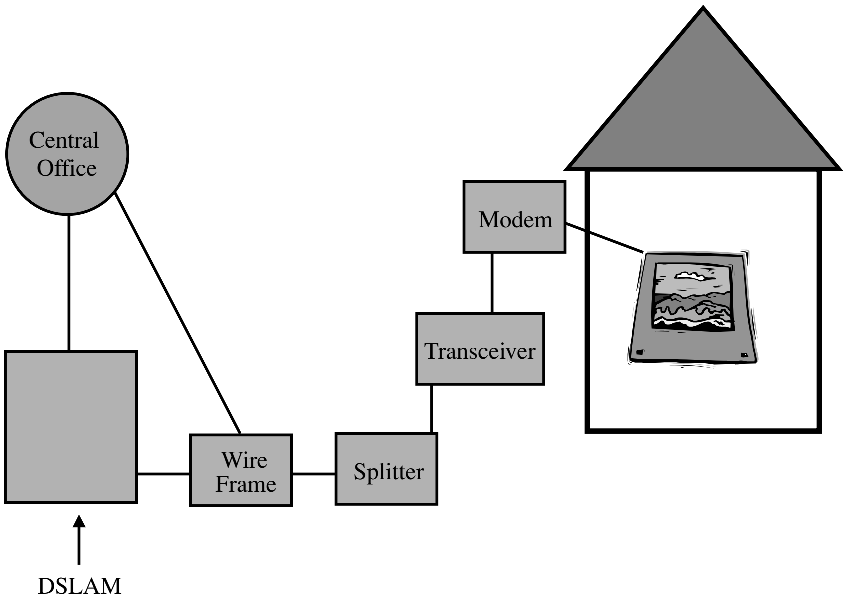

FIGURE 4.7 The DSLAM

TYPES OF XDSL

xDSL requires changes to the outside plant but is far less costly than a total replacement of the local wire. There are several different "flavors" of digital subscriber line technology:

- High Data Rate Digital Subscriber Line (HDSL)
- Very High Data Rate Digital Subscriber Line (VDSL)
- ISDN Digital Subscriber Line (IDSL)
- Single-Line Digital Subscriber Line (S-DSL)
- Symmetric Digital Subscriber Line (SDSL)
- Asymmetric Digital Subscriber Line (ADSL)
- Rate Adaptive Digital Subscriber Line (RADSL)

Each flavor was designed to meet certain perceived market needs, and all these versions of xDSL technology are vying for the position of de facto industry standard. At the time of writing,

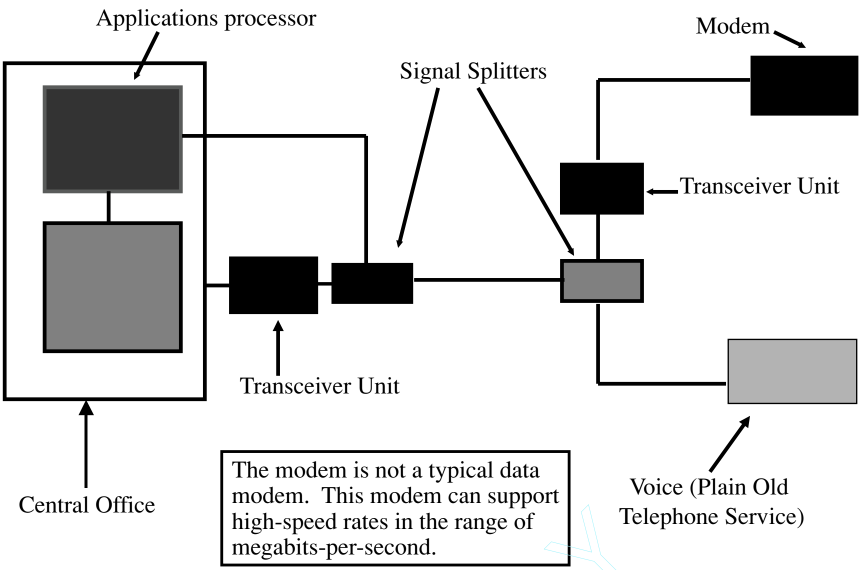

FIGURE 4.8 xDSL Network Configuration

all of the versions are seeking some form of standardization in the industry from a body known as the ADSL Forum. The primary differences between the technology versions are the transmission distance between the switch and the customer premise and the data rates each supports. The distance issue is not minor—the distance over which each technology can transmit has a direct impact on the carrier's (or CLEC's) cost structure. The data rate also has an impact on the cost structure of the CLEC. The following subsections briefly describe the various versions of xDSL.

High Data Rate Digital Subscriber Line (HDSL)

HDSL technology was the first of the xDSL technologies developed in 1991–1992. The goal of HDSL was to deliver T-1 services and capabilities directly to the home or small business over two pairs of twisted wire (four wires).

HDSL supports the splitting of the T1 bit rate (1.544 Mbps) over the two pairs of wire. Splitting the total bit rate across four versus two wires enables the carrier to transmit lower frequencies across a single wire (in the four-wire configuration) versus higher frequencies on a single wire (in the two-wire configuration). See Table 4.1 for data rates.

VERY HIGH DATA RATE DIGITAL SUBSCRIBER LINE (VDSL)

VDSL technology splits the transmitted bandwidth across a single twisted-pair. VDSL is an asymmetric form of DSL. There is an Asymmetric Digital Subscriber Line (ADSL) technology; VDSL is a variation of ADSL. The application for VDSL is in the area of high-bandwidth–intensive applications such as high-definition video. See Table 4.1 for data rates.

ISDN DIGITAL SUBSCRIBER LINE (IDSL)

IDSL technology was created to support ISDN to the home. IDSL is a dedicated service that supports only data, not video. IDSL does not support the full range of ISDN services available under ISDN, but like ISDN, IDSL requires a separate line to the home or business. From an execution perspective, IDSL utilizes the same modem and transceiver units as the other forms of xDSL but also uses standard ISDN terminal adapters at the subscriber's premise. See Table 4.1 for data rates.

SINGLE DIGITAL SUBSCRIBER LINE (S-DSL)

S-DSL is a variation of HDSL and is also known as HDSL2. S-DSL supports HDSL over a single twisted-pair. However, data rates are different for downstream (service provider to the subscriber) and upstream (subscriber to the service provider). See Table 4.1 for data rates.

SYMMETRIC DIGITAL SUBSCRIBER LINE (SDSL)

SDSL is also a form of HDSL, but data rates are symmetric for the downstream and upstream applications. According to the ADSL Forum, SDSL is a version of HDSL and POTS (Plain Old Telephone Service) and can be provisioned over a single pair of wires as opposed to two pairs of wires. See Table 4.1 for data rates.

ASYMMETRIC DIGITAL SUBSCRIBER LINE (ADSL)

At the time of writing, ADSL is currently the more popular version of xDSL. Equipment to support ADSL is available and is being deployed widely not only by CLECs but also by ILECs. ADSL appears to be the "middle ground" between technology and cost–benefit. ADSL is capable of supporting video, voice, and data, as can other versions of xDSL. However, the difference is that ADSL technology is available for CLECs that are seeking to jump into business now and not tomorrow. More often than not, the deciding factor for one technology's victory over another is availability. Because ADSL technology is being deployed, and therefore generating profit for the manufacturer and the service provider, the cost of the technology is in fact lower than that of other xDSL technologies.

The asymmetric nature of ADSL technology enables the service provider to run three separate channels over the same wires. One channel carries voice, like POTS. The second channel carries signaling at a rate of 16–640 Kbps to the network. The third channel is a higher speed data connection operating at a rate ranging from T-1 (1.544 Mbps) to 6.1 Mbps (in some vendors' systems this rate can go as high as 9 Mbps). The second channel is used for uploading information from the subscriber to the network. The third channel is used for downloading information from the network to the user or subscriber.

A CLEC gets the most out of the pair of wires used; instead of two channels, three channels are supported. An ILEC is also getting the most out of the pair of wires and can rapidly meet the challenges presented by competition.

From an execution perspective, ADSL can be provided on a one-on-one basis—the necessary equipment upgrades can take place one subscriber at a time. Upgrades to a neighborhood or a community can take place in a controlled fashion.

ADSL deployment requires that the following equipment be installed:

- ADSL Transceiver Unit Central Office (ATU-C)
- ADSL Transceiver Unit Remote (ATU-R)

- Discrete Multi-Tone (DMT) Modem. If fiber to the home or business is available then the DMT modem is not needed; a modem is still needed at both the subscriber and service provider locations to multiplex the channels to the customer.
- ADSL repeaters. The first one only needs to be installed 18,000 feet from the central office.

It is interesting to note that both the CLECs and the ILECs saw the same applications for ADSL. Given the current and future state of competition in the local loop market, the ILECs see ADSL as a way of finally converging voice, video, entertainment, data, and Internet access business opportunities using the existing (enhancements notwithstanding—the infrastructure remains largely unchanged) infrastructure.

An interesting twist to the local loop scenario is that CLECs are deploying the same technology directly to the subscriber by leasing dark or dry loops (no controlling electronics) from the ILECs and deploying their own ATU-Cs in the ILEC central office switching facility. Collocation of CLECs in ILEC buildings is allowed under the Telecommunications Act of 1996.

RATE ADAPTIVE DIGITAL SUBSCRIBER LINE (RADSL)

RADSL is a version of ADSL that uses intelligent ADSL modems designed to sense the performance of the loop and adjust transmission speeds accordingly. Effectively, RADSL supports both asymmetric and symmetric transmission of data.

ADVANTAGES OF xDSL

There are advantages to deploying xDSL, which is why an entire industry looks to it as a local loop technology. xDSL is a tool for the CLECs to penetrate the local loop; to the ILECs, xDSL is a way for them to enhance their local loop assets and maintain control of access to the customer. These advantages, like the disadvantages described later, have impact on both the ILECs and the CLECs.

TABLE 4.1 xDSL Data Rates

XDSL Technology	Data Transmission Rates	Directionality/ Mode	Loop Range Estimates: Distances Between the Customer and the Switch	Number of Wire Pairs
HDSL	1.544 Mbps (each pair of wires will transport data at a rate of 784 kbps)	Two Way (Duplex)	10,000 to 12,000 Feet	2
VDSL	1.544–2.3 Mbps	Upstream	4,500 Feet	1
	13–52 Mbps	Downstream	4,500 Feet	1
ISDL	128 kbps	Duplex	18,000 Feet	1
S-DSL (HDSL2)	1.544 Mbps	Duplex	12,000 Feet	1
SDSL	1.544 Mbps	Duplex	10,000 Feet	1
ADSL	1.544–2 Mbps	Downstream	18,000 Feet	1
	1.544–6.1 Mbps	Downstream	12,000 Feet	1
	16–640 kbps	Upstream	18,000 Feet	1
RADSL	640 kbps–7 Mbps	Downstream	12,000 Feet	1
	128 kbps–1 Mbps	Upstream	18,000 Feet	1
	640 kbps	Duplex	18,000 Feet	1

- xDSL technology can assist a wireline telephone company in keeping its subscriber base from jumping to another carrier, like a cable TV company.
- Most lines to homes and small businesses are still analog, therefore the ILEC can continue to gain value from existing outside plant. xDSL provides a way of serving subscribers with minimal impact on the service provider's network.
- CLECs may find technologies like ADSL useful in starting up their networks quickly and in a cost-effective manner.
- CLECs face high startup costs and short market windows: xDSL offers a way to provide a competitive service to the incumbent LECs. (xDSL should not be considered the

answer to a CLEC startup's problems, because there are so many other issues involved. xDSL, however, allows a CLEC or other carrier to differentiate itself by providing high-speed data services to the subscriber.)

DISADVANTAGES OF xDSL

Despite the very apparent advantages of xDSL technology, there are disadvantages:

- To upgrade to xDSL, telecom operators need to install xDSL equipment at both ends of the loop connecting the subscriber and the central offices. This brings with it the headaches of deploying any equipment in the field; coordinating with customers to find time to enter the home, finding space for the equipment in the home, fielding questions from the customer, etc.
- A potential drawback for customers is that equipment from different vendors is likely to be incompatible.
- There is a need to make some modifications or change-outs of repeaters on the loop, which leads to additional costs.
- The cost is at both ends of the loop. Carriers must answer the questions: "Who will pay for this? And how will the service be paid for?"

COAXIAL CABLE

Coaxial cable was and still is the primary transmission facility used by Community Access Television (CATV) systems, also generically known as cable TV. For many years, coaxial cable was a metallic transmission medium heavily used to carry large bandwidth information streams over distances greater than 600 feet. For a time in the mid-1980s, ILECs briefly flirted with the idea of using coaxial cable in the local loop to provide bandwidth.

There are two types of coaxial cable: broadband and baseband. Broadband coaxial cable is typically used for cable television. Baseband coaxial cable was used for data network connections in earlier implementations. Baseband systems are not necessarily cost effective, given that baseband can only support a single channel.

As a transmission medium, coaxial cable is classified as unbalanced. The information is sent through one conductor, while another conductor is used as the electrical ground. Figure 4.9 illustrates the construction of coaxial cable.

Coax consists of an inner and an outer conductor. As the diagram shows, coaxial cable has an inner conductor made from some type of metallic material (normally copper). The inner conductor is surrounded by a nonconductive material. This dielectric material is also surrounded by a sheath of conductive material, normally made of copper. The outer conductor is braided so that it bends easily about the dielectric material. It is surrounded by an insulating material. Coaxial cable is used for a variety of construction purposes, like fluorescent lighting wiring. It is used for telecommunications and cable TV, but coaxial cable is no longer seen as a viable long term option for the local loop.

HYBRID FIBER–COAXIAL CABLE

As we noted, in the early to mid-1990s optical fiber was a very expensive medium, so an alternative called hybrid fiber–coaxial (HFC) cable was developed. Hybrid fiber coaxial cable is a combination of fiber optics and coaxial cable. It was created to facilitate the entry of large established wireline carriers and new startups into the multimedia business.

As with many product ideas, there was no single vision of what multimedia meant or what it was to provide or even to whom it would be provided. What was understood was that in order to take the first step toward providing more bandwidth to the home or business, the telecommunications industry needed first to break down the transmission facility cost barrier. The largest users of hybrid fiber–coaxial cable became the cable TV

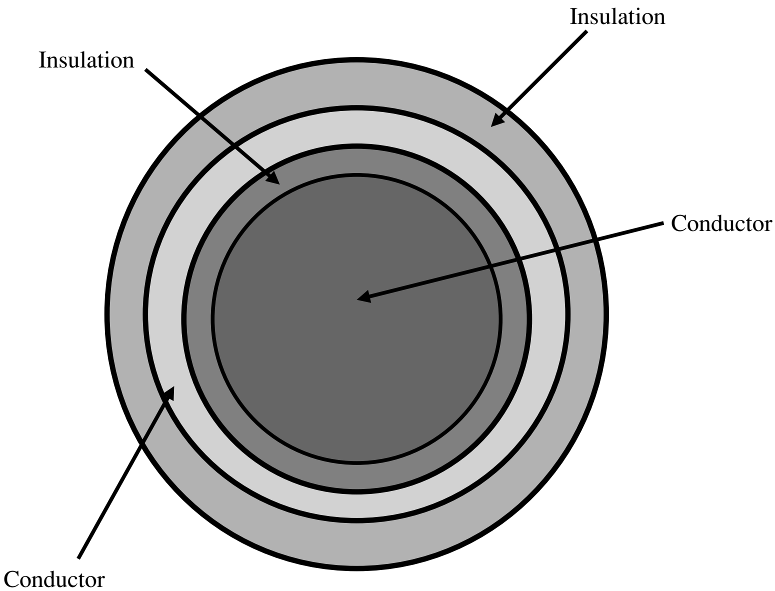

FIGURE 4.9 Coaxial Cable

companies. The wireline telephone companies found the system useful in only limited applications. By the time hybrid fiber–coaxial cable became commercially viable, a great deal of work had already been completed in the area of fiber optic transmission. Furthermore, by the late 1980s and early 1990s the ILECs believed demand for bandwidth was not large enough to warrant an investment in hybrid fiber–coax since other technologies were being developed. (The deployment of any technology or product is usually influenced by market demand and the development of competing technologies.)

Hybrid fiber–coaxial cable built on the strengths of coaxial cable using optical fiber as the catalyst. Hybrid fiber–coax is not coaxial cable with fiber wrapped around it: The term hybrid refers to the way in which the total CATV trunking and feeder cable system is constructed. In hybrid fiber–coaxial cable, the trunking portion of the cable television system is replaced with fiber optic cable. The service drops are still coaxial cable. This system must use an optical-to-electrical conversion of the signal. See Figure 4.10 for an illustration of hybrid fiber–coaxial cable.

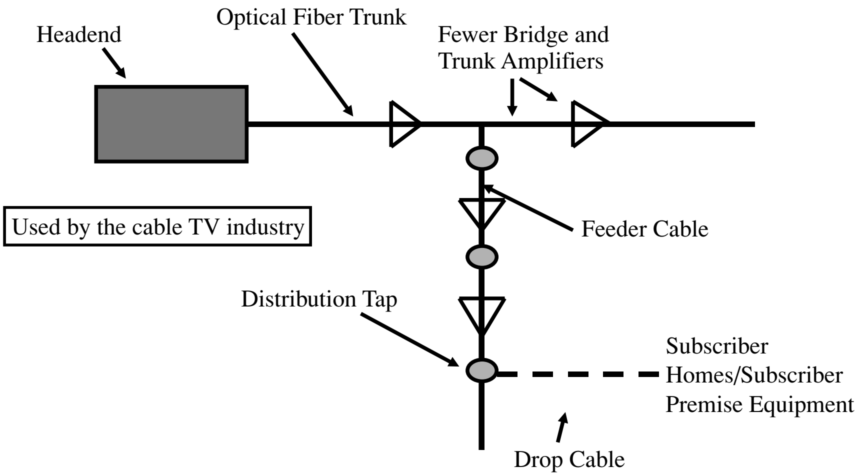

FIGURE 4.10 Hybrid Fiber–Coaxial Cable

Hybrid fiber–coaxial cable system advantages include:

- Higher bandwidth
- Lower signal impedance
- Improved signal-to-noise ratio
- Less thermal noise attenuation
- Less attenuation from ambient electromagnetic fields from other surrounding transmission systems that share the same telephone pole or transmission conduit

These advantages enable the hybrid fiber–coaxial cable system to:

- Reduce the number of signal repeaters in the field, which means less capital equipment to install and maintain.
- Maintain a greater range for the transmission signal without having to use a signal repeater.
- Perform less field maintenance on the trunking system.
- Have overall greater reliability by virtue of the fact that there are fewer individual pieces of equipment to maintain.

Despite its obvious benefits, hybrid fiber–coaxial cable is not heavily deployed. Competing technologies and market conditions have affected the carriers' need or desire to deploy this transmission technology.

METAL VERSUS FIBER: DECISION PROCESS

The reality is that glass has a number of inherent advantages over metal. What drives the telecommunications community to continue to deploy metal is that there are no compelling business cases to deploy fiber to the curb (FTTC).

The transmission of information across the various networks requires specific technologies—there are high-speed roadways that interconnect communities (a network backbone); there are streets that run through a town or city (interoffice, interswitch connectivity); there are local roads leading to homes and businesses (the local loop). In some cases fiber is more suitable than metal; in other cases, metal is more suitable than glass. A provider needs to determine bandwidth requirements and translate those requirements into the appropriate technical requirements.

Understanding the relationships between the various networks and the elements within a network is key to understanding how best to select transmission media. Until the business case is written that supports local loop fiber deployment, the medium of choice will be copper. Not only does this business case need to be written, but it needs to be proven. "Proven" means it must meet its "numbers," and "numbers" means money. Figure 4.11 illustrates this point.

SUMMARY

Metallic transmission technology has not lost its allure. Despite the fact that much of the industry talk is about fiber and wireless, the economic reality is that metal still has a place in the industry. As abhorrent as it is to many engineers,

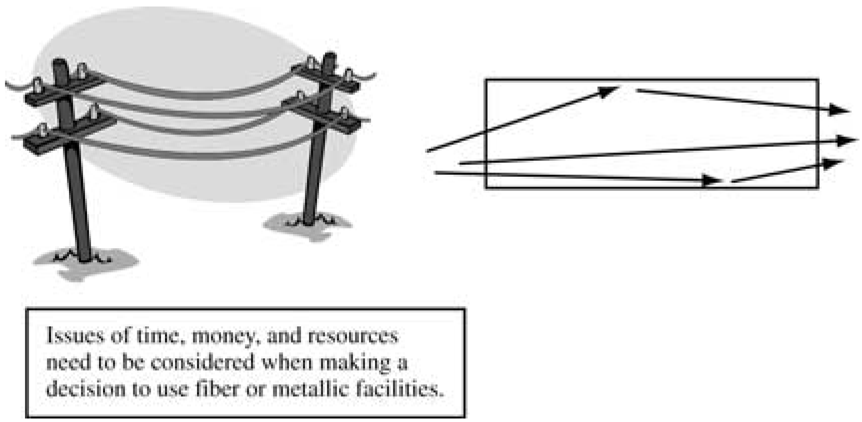

FIGURE 4.11 Metal versus Fiber

business drives industry. Technology is a tool, and technology must be deployed in the context of meeting market needs.

Many companies jumped into the xDSL business to deploy xDSL technology into the local loop. The tragedy is that many of these carriers went bankrupt. These CLECs shut down because they lost investment funding, or had a poorly executed business plan. It is likely that the remaining CLECs will rise out of its own ashes and take advantage of whatever xDSL facilities have been left by these bankrupt companies.

The xDSL facilities used will support Internet access and may be able to support the various streaming media applications that are envisioned. xDSL's ability to support streaming media in a commercially acceptable fashion, however, will be dependent on market expectations.

CHAPTER FIVE

WIRELESS BROADBAND TECHNOLOGIES

Wireless broadband technologies are defined as telecommunications that are wireless and support data at rates greater than 14.4 kbps. During the early 1990s, cellular carriers operating in the 800 and 900 MHz bands in North America and Europe were capable of carrying low-speed data up to 9.6 kbps. Standards supported data transmission at speeds up to 14.4 kbps. Industry associations had at one time defined broadband wireless as radio technology capable of supporting data speeds at 128 kbps and higher. This appears to be a good working definition.

Wireless broadband is supported by a multitude of technologies and provisioning implementations. It can be provided by radio frequency (RF) technologies such as Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and Global Systems for Mobile Communications (GSM). The goal of all carriers is to meet customers' needs, regardless of how the underlying technology works. Wireless broadband services can be provided by cellular, PCS, or line-of-sight (LOS) carriers. (Some industry professionals claim that wireless broadband services refer to LOS systems only. I do not subscribe to this position.) The LOS carriers most commonly referred to in industry trade magazines are those classified as either Local Multipoint Distribution Service (LMDS) or Multichannel Multipoint Distribution Service (MMDS) carriers.

This chapter is not intended to support one radio technology over another. The plethora of technologies being investigated and implemented are driven by the perceived need to provide wireless telecommunications subscribers with the ability to access the Internet. Many radio engineers prefer one technology over another, and the debates between radio engineers regarding the relative merits of radio technology border on the religious.

I use the words "perceived need" because there are many in the industry who do not believe there is a market need for wireless Internet access. I disagree; until now there has been no way for carriers to present data in a fashion that makes the Web navigable from a small handset.

Research in polymer displays may yield the first unfolding handset screen, allowing users to navigate the Web with a small handset and its associated display.

WIRELESS BROADBAND IMPLEMENTATIONS

Because the technology used depends on the wireless industry business segment being discussed, it is important to understand wireless broadband implementation. Wireless business segments are broadly represented by:

- Cellular/Personal Communications Services (PCS)
- Satellite
- Wireless local loop

These business segments are investigating ways of providing wireless broadband services to their customers. Each has taken an approach that optimizes its radio licenses and the business space in which it has chosen to operate. See Figure 5.1.

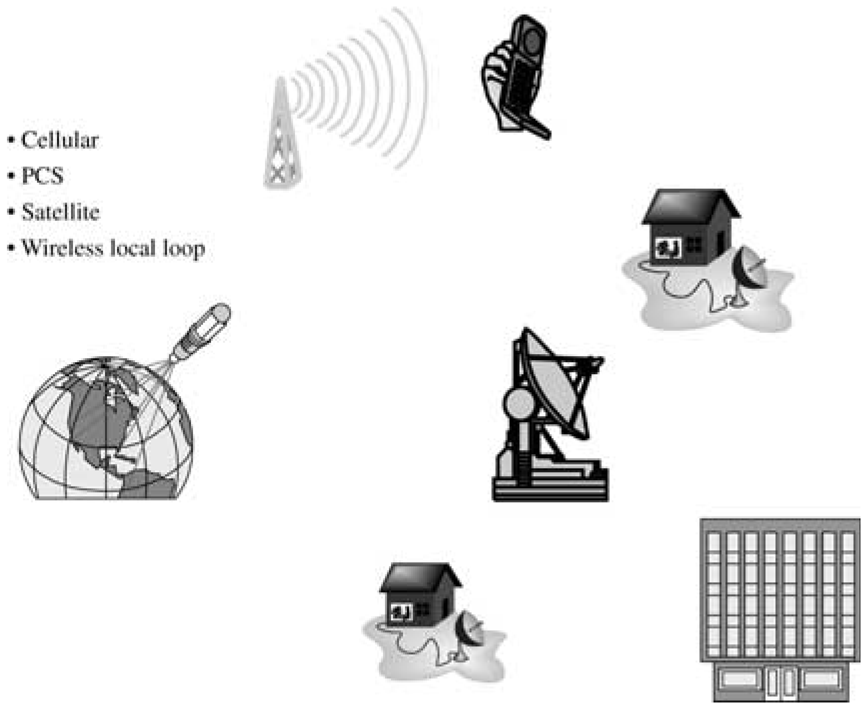

FIGURE 5.1 Wireless Broadband: What Is It?

CELLULAR/PERSONAL COMMUNICATIONS SERVICES (PCS)

Cellular and PCS are the most popular forms of wireless broadband services. The following subsections describe the types of carriers, implementations, and radio technologies used in cellular and PCS systems.

CELLULAR CARRIERS

In 1946, two-way mobile radio service was introduced. Soon after its introduction, its disadvantages and weaknesses became apparent. From a customer's perspective, there was the issue of competing RF channels and interference. The same held true from an engineer's perspective. The technical challenges were how to go about giving subscribers a larger pool of RF channels from which to make their calls and reducing interference between subscribers. The quick and simple solution would have been not to worry about giving subscribers more RF channels, but to physically separate radio coverage areas to ensure that there would be no overlap. Fortunately no engineer took that approach. To manage radio coverage in such a manner would have been foolish for it would reduce one's ability to provide service to customers in a single large area and upset customers because their calls would suddenly drop (end).

Instead, engineers from Bell Telephone Laboratories (today known as Bell Laboratories) began to explore a concept that would reuse frequencies in small radio coverage areas. These coverage areas (called cells) would be linked together using a switch that would enable calls to be made while the caller was moving. Computer and switching technology had to improve before mobile radio service became commercially viable and even then, availability was an issue because of regulatory delays.

Cellular service became commercially available in the United States in 1983. Today there are two basic radio technologies

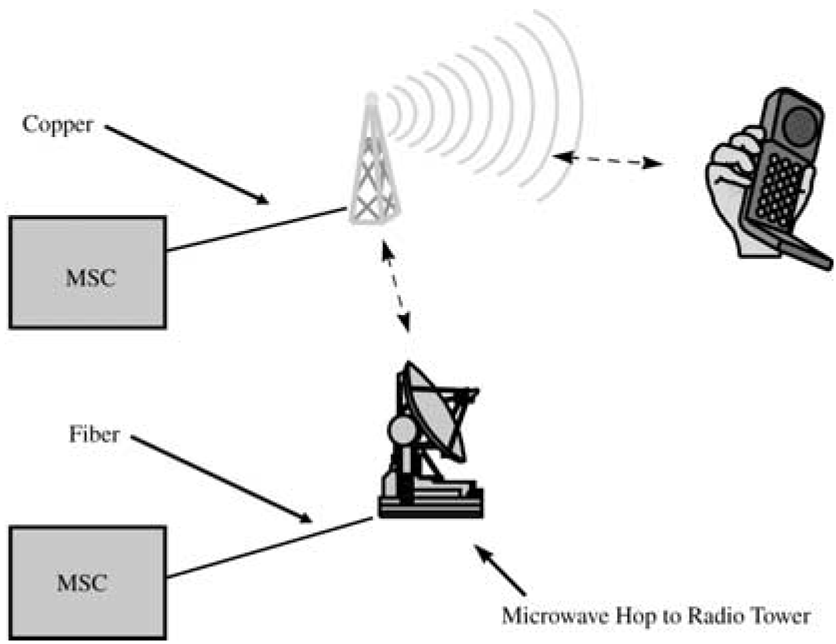

FIGURE 5.2 Cellular Carrier System

used in the cellular world: analog and digital cellular. Figure 5.2 is a representation of a cellular system.

PERSONAL COMMUNICATIONS SERVICES (PCS)

In 1994, the term Personal Communications Services (PCS) was originally envisioned to encompass a broad range of services designed to allow people to access the public switched telephone network (PSTN) regardless of their physical location. Today most people believe PCS to be digital cellular, something better than cellular or cellular without the old baggage of legacy equipment. PCS carriers operate in the 1900-MHz band in North America and in the 1800-MHz band in Europe.

In the mid-1990s many people envisioned PCS with features that supported terminal personal and service mobility. PCS would combine the many emerging intelligent network capabilities of the public networks (CCS, ISDN, and IN) with sophisticated wireless access technologies and related radio network mobility control capabilities. PCS would bring high-speed data to the mobile user.

From a technical and conceptual standpoint, there isn't much difference between cellular service and PCS. The same engineering practices are employed and the same traffic design techniques are used. The differences between early implementation of PCS and cellular are:

- New carriers holding PCS licenses had to contend with high capital costs for equipment and deployment.
- New PCS carriers faced competition from day one. In their infancy, cellular carriers did not have much competition to worry about.
- The competitors were both new and established. During 1994, when licenses were being awarded via spectrum auctions in the United States and shortly thereafter in Europe, existing cellular carriers had been allowed to bid for PCS licenses. The only catch was that the cellular carriers had to create completely new and separate companies to build and operate a PCS network.

- PCS carriers were at the cutting edge of technology, and it was expected that they would install the latest technology. Cellular carriers were expected to do the same thing, but still maintain an established equipment base.
- PCS carriers had a fraction of the time needed to make their networks commercially operational. They had to work hard and fast to capture market share. They had the disadvantage of building a new network infrastructure as rapidly as possible in order to make money as quickly as possible.
- Many PCS carriers had to spend a lot of money to obtain their licenses. The recent reauctioning of the C-Block licenses (in the United States) and bankruptcy proceedings of many carriers allowed existing cellular carriers to buy up bankrupt carriers' spectrum and in some cases their infrastructure.

In retrospect, the various PCS auctions were a good thing for many industry players and investors seeking new opportunities. The recent spate of failures and bankruptcies has little to do with technology and market expectations, but a great deal to do with poor business plan execution. Figure 5.3 is an illustration of a PCS carrier system.

Today most customers and industry players see the market and the PCS and cellular spectra as nothing more than additional resources for those carriers who are now known generally as wireless carriers. Figure 5.4 is a representation of this point.

Wireless carriers are currently working toward migrating their networks toward a technology state that has become known as 3G (Third Generation). 3G is viewed as the next generation of wireless. First-generation wireless systems were old analog cellular systems that did not support roaming. Second-generation wireless systems are comprised of digital cellular and PCS networks; these systems include the text-based Internet Web access products supported by the wireless carriers. Some TDMA, GSM, and CDMA wireless carriers call their networks 2.5G networks because they support this limited Web access and limited data services. 3G is defined as wireless broadband capability.

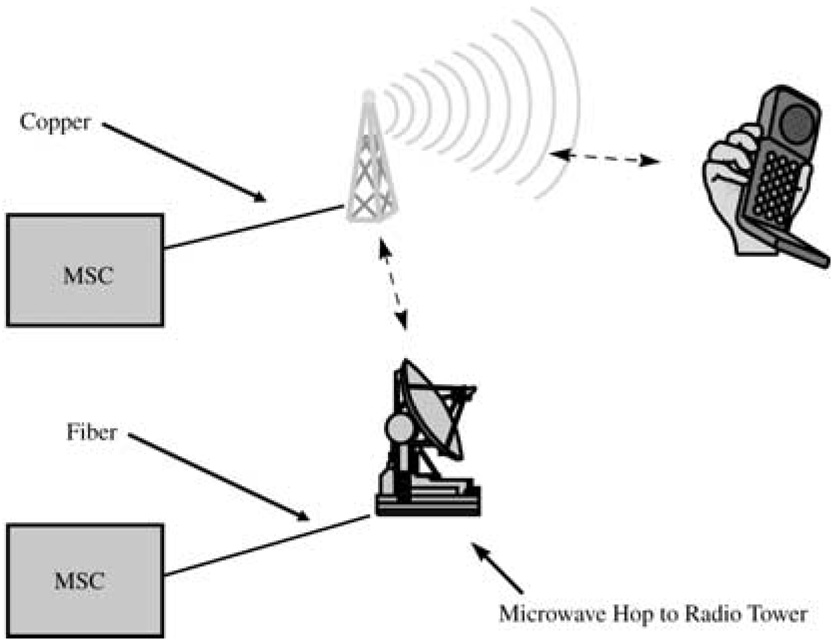

FIGURE 5.3 PCS Carrier System

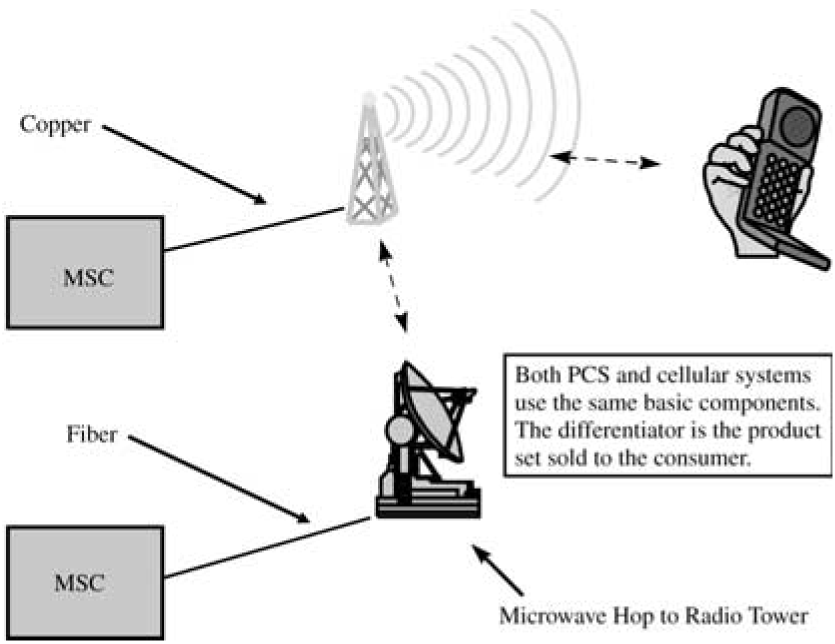

FIGURE 5.4 PCS and Cellular: The Same

WIRELESS BROADBAND IMPLEMENTATIONS: CELLULAR AND PCS CORE DISCUSSION

It is assumed that the next generation (3G) of wireless will be supported by all cellular and PCS carriers regardless of whether their basic radio technology is TDMA, CDMA, or GSM.

WHAT IS 3G?

The Untied States Federal Communications Commission (FCC) defines 3G in terms of user capabilities. The following are some of the 3G capabilities defined by the FCC:

- Supports circuit and packet data
  - Data rates of 144 kbps or higher in a mobile environment
  - 384 kbps for pedestrian traffic
  - 2 Mbps or higher for indoor traffic
- Interoperability between vendor systems and possibly carriers.
- Roaming is supported
  - Standardized call detail record formats
  - Standardized user profile formats
- Capable of determining the geographic location of mobile devices
- Supports multimedia services and capabilities
  - Fixed and variable rate bit traffic
  - Bandwidth on demand
  - Asymmetric data rates in the forward and reverse radio links
  - Multimedia mail store and forward
  - Broadband access up to 2 Mbps

This list is a guide to the discussion that follows. The FCC's approach was to use customer requirements to define the product called 3G. Focusing on the customers' needs is essential for this and any other product.

There are three core radio technologies in commercial global service today: TDMA, CDMA, and GSM. All the 3G implementations under investigation and being prepared for commercial rollout are based on TDMA, GSM, iDEN (a GSM derivative), and CDMA. Some other wireless broadband services being developed and under consideration for deployment are:

- High-Speed Circuit Switched Data (HSCD)
- General Packet Radio Service (GPRS)
- Enhanced Data Rates for GSM Evolution (EDGE)
- Wideband CDMA
- CDMA2000

These are more than just services; they are enhancements to the core radio technologies supporting cellular and PCS systems worldwide and the underlying radio technologies for the wireless broadband services that carriers are hoping to provide. The following three sections describe the core radio technologies that serve as the foundation for these broadband technologies: TDMA, GSM, and CDMA.

TIME DIVISION MULTIPLE ACCESS (TDMA)

TDMA is a narrowband digital radio technology. TDMA time division multiplexes a radio signal into 30-KHz slices. Each slice is dedicated to a subscriber on a call. TDMA was first introduced by the Telecommunications Industry Association (TIA) in the early 1990s. The TIA is an ANSI-accredited North American standards body, specializing in wireless standards. The original TDMA standard was called Interim Standard (IS)-54. IS-54 was modified to include digital control channels, which led to the creation of the standard called IS-136. Figure 5.5 is an illustration of the TDMA waveform.

TDMA IS-54 was first deployed in the cellular 800-MHz bands in North America. The IS-54 radio signal used the same control channel format as the cellular analog system (known as Advanced Mobile Phone Service). Each communication channel is comprised of two 30-KHz channels: one for the forward link and one for the reverse link. The forward link is the communications channel from the cell site to the mobile handset. The reverse link is the communications channel from the mobile handset to the cell site. Figure 5.6 is an illustration of the forward and reverse links in a TDMA system.

In addition to the communications channels, also known as traffic channels, there is a control channel. This sets up the call and passes control information between the handset and the cell site. The reason the cellular industry moved to a digital format was twofold: better voice quality and more channel capacity for the same amount of spectrum as an analog call.

Digital wireless calls have less noise and higher intelligibility than analog calls. Digital calls can use multiplexing methods to increase the number of subscribers carried over the same amount of bandwidth that carriers were using for analog wireless. In the IS-54 TDMA system, three subscribers can share the same traffic channel. In an analog conversation, a single subscriber is using a single 30-KHz traffic channel. In an

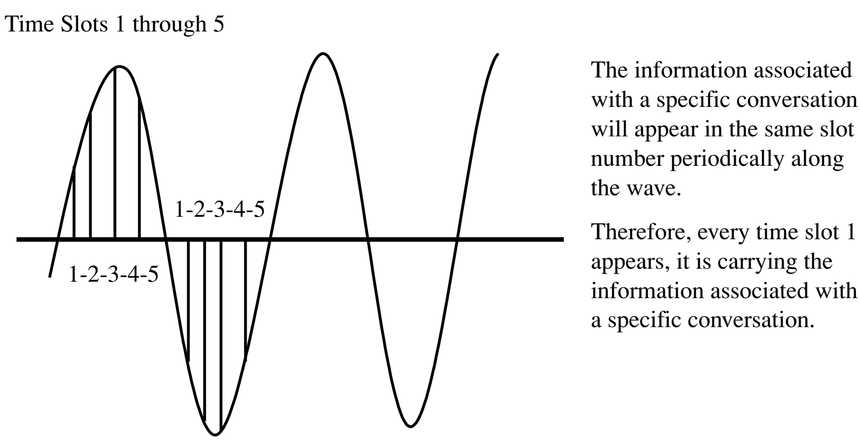

FIGURE 5.5 TDMA Waveform

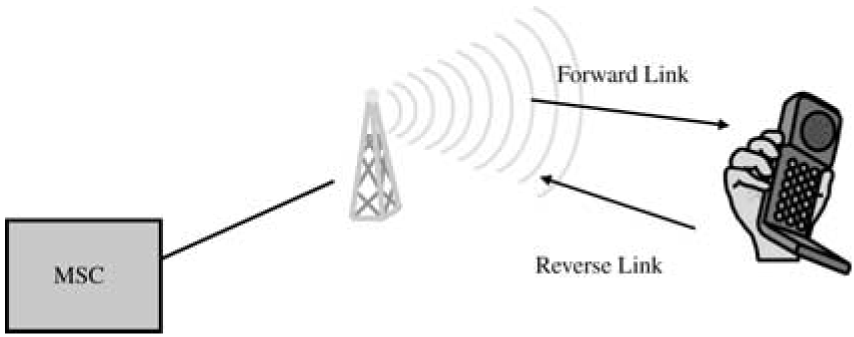

FIGURE 5.6 Forward and Reverse Links

IS-54 system, three users share the single traffic channel by slicing the channel into smaller slots. IS-54 systems can support dividing the 30-KHz channel into six time slots. The TDMA systems support up to six users per traffic channel, but the capability has not been exploited; deployments typically only support three users per traffic channel.

IS-54 conversations (channels) are divided into smaller time slots, only 20 milliseconds long. Each mobile is allowed to use only one third of the 20 ms slot. A component called the speech coder compresses the voice into a coded bit stream. The speech coder is the key to the performance of the TDMA system: If the speech coder does its job well, the user notices less noise than in an analog system.

During a voice conversation, TDMA systems enable a subscriber to use every third slot for a conversation, while these slots not being used by the subscriber may be used by another subscriber. For example, Subscriber A's handset will transmit on time slots 1 and 4, Subscriber B's handset will transmit on time slots 2 and 5, while Subscriber C's handset will transmit on timeslots 3 and 6. Figure 5.7 illustrates this channel structure.

In reality, subscribers are transmitting and receiving at the same time. (At least, that is what the subscriber sees, even though, in reality, IS-54 mobiles do not actually transmit and receive simultaneously.) Speech is transmitted and received in an alternating manner that appears to be continuous. Figure 5.8 illustrates this concept.

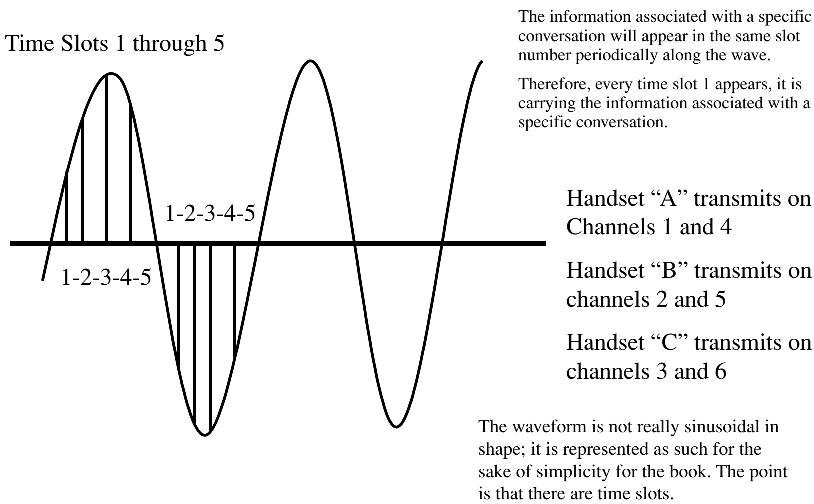

FIGURE 5.7 TDMA Channel Structure

Note that the subscriber's handset is transmitting and receiving on different frequencies; this is referred to as full duplex. The transmit takes place on one frequency while receive takes place on another frequency; the transmit and receive frequencies are separated by 45 MHz. By contrast, a simplex transmission is one in which the two parties share the same communications frequency, and only one of the parties may speak at a time. One example of a simplex device would be a walkie-talkie.

The problem with IS-54 lies in the fact that the control channel structure is identical to that of the analog control channel. This means that IS-54 TDMA systems are limited to the services supported by the analog control channel. The only way to get around this limitation is to change the control channel structure. Furthermore, IS-54 cannot support the 1900-MHz spectrum band used in North America for the PCS systems.

To address these problems, IS-136 was proposed. IS-136 added a number of features to TDMA technology, including:

- Paging classifications
- Short Message Service (SMS)

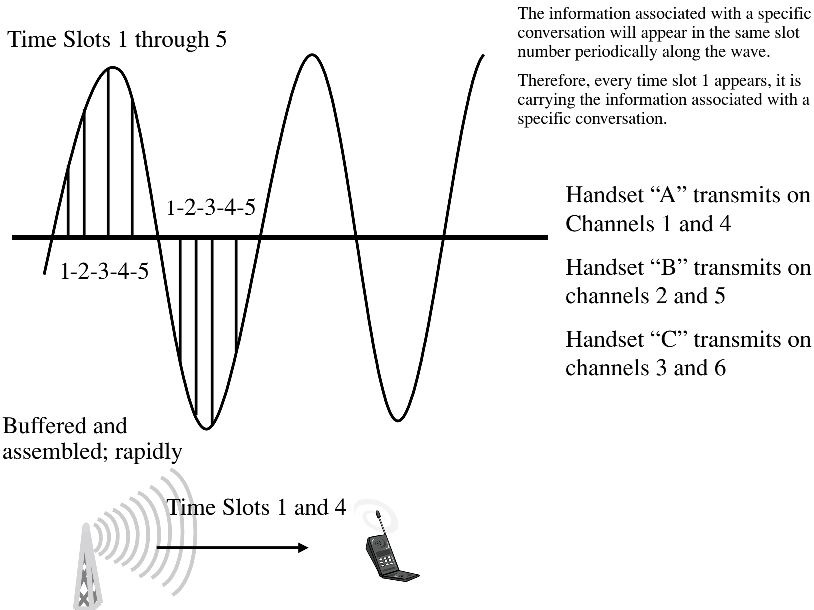

FIGURE 5.8 TDMA, IS-54 Time Slots

- Faster data transmission
- Control channel reselection
- Digital Control Channel (DCC)

The structure of an IS-136 TDMA system is physically similar to that of an IS-54 cellular system. The most important modification introduced by the IS-136 standard was the digital control channel (DCC), a control channel designed to carry the same kind of system management and paging information as the control channel of an IS-54 system, but in a digital format, thereby providing for additional capabilities in the system as a direct result of the new DCC.

The time slots are 40 ms long and divided into six segments. The DCC is comprised of several logical control channels. These channels enable the following features:

- *Broadcast Control Channel (BCCH).* Contains general information on all subscribers

- *Multi-function Radio Channel.* Allows multiple users on a radio channel
- *Short Message and Paging Channel (SPACH).* Combines the short message service, paging and access channels
- *Random Access Channel (RACH).* Coordinates random access attempts to the system
- *Paging Channel (PCH).* A multiplexed channel designed to optimize the sleep time available to a mobile handset. Since the PCH is multiplexed, there are, in fact, multiple groups of paging channels. Each group of channels has a different time period in which it is either active or transmitting a page: Therefore the PCH is directly related to the "inactive or sleep mode" period.
- *Access Response Channel (ARCH).* A shared channel that the mobile handsets use for sending information
- *Short Message Service Channel (SMSCH).* Sends short message data between the handset and the cell site. IS-54 can support SMS messages but only on the traffic channel.
- *Fast Broadcast Control Channel (F-BCCH).* An extension of the BCCH. This channel constantly transmits information about the state of the system between the cell site and the handset. This channel transmits critical information.
- *Extended BCCH (E-BCCH).* Transmits information about the system less critical than that carried information on the F-BCCH. The TDMA system prioritizes the information being transmitted by the system in order to utilize system resources efficiently.

GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS (GSM)

The air interface (radio) and fixed-network specifications known as Global System for Mobile Communications (GSM) are a Pan European suite of standards designed to address the 900-MHz and 1800-MHz needs of the Pan European market. Unlike radio standards developed in North America, GSM standards were developed with an end-to-end perspective. In North

America, radio standards and network message sets associated with the fixed or wireline portion of call setup and processing were developed independently of each other.

The GSM traffic channel is 200 KHz. This is much larger than either AMPS or TDMA traffic channels. GSM enables multiple users to use this 200-KHz channel. GSM time division multiplexes the channel into eight distinct time slots. These slots, like the TDMA system, support both control and traffic channels. What is interesting to note about GSM is that it predates TDMA in North America by a few years. However, the GSM suite of standards, when published by the international standards community, was a robust set of standards. It contained network and radio message sets that supported a range of voice, low-speed data services, and system management features that the first version of the TDMA standards did not have. GSM supported (and still does) features such as subscriber identity module (SIM) cards, data services, facsimile services, and mobile-assisted handover capabilities. The GSM system was ahead of its time when first published in 1990. Physically, the GSM network looks the same as the TDMA or AMPS system. Figure 5.9 shows a GSM system.

In order for GSM to enable multiple users to share a 200-KHz channel, the system must time-multiplex the channel into frames no larger than 4.615 ms. The resulting number of frames is 26. Like TDMA, the GSM system is capable of enabling multiple users to share bandwidth by using alternate frames. GSM control channels are subdivided into logical control channels, which are shared along with the 26 frames. GSM control channels are capable of supporting a wide variety of functions such as facsimile services, low-speed data, sleep mode, power control, and mobile-assisted handover.

CODE DIVISION MULTIPLE ACCESS (CDMA)

CDMA was standardized in North America by the Telecommunications Industry Association (TIA), and became known as IS-95.

Physically, a CDMA carrier system looks like any other wireless system. However, CDMA introduced a concept that

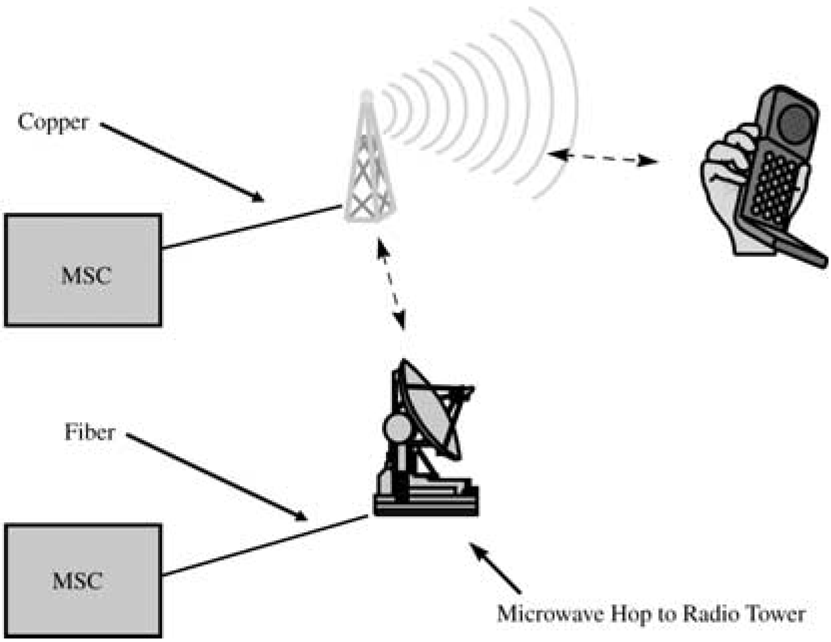

FIGURE 5.9 GSM System

requires a Mobile Switching Center (MSC) to monitor and maintain communications between all base stations: the soft handoff.

CDMA divides the radio spectrum into 1.25-MHz slices. CDMA takes a conversation and multiplexes it across the entire 1.25-MHz slice concurrently with other conversations. Whereas TDMA and GSM keep the conversation restricted to a specific frame in a sequence of frames, CDMA spreads the conversation among multiple frames and at the same time encodes each frame. The only way to capture and listen to someone else's conversation is with the unique code to decode the frames. Figure 5.10 is a representation of a CDMA waveform.

On a more technical level, CDMA spreads a voice conversation across the frequency band and encodes the signal with a pseudorandom noise (PN) code. The mobile handsets are also unique because they are capable of correlating with the correct PN sequence. Each CDMA channel is divided into 64

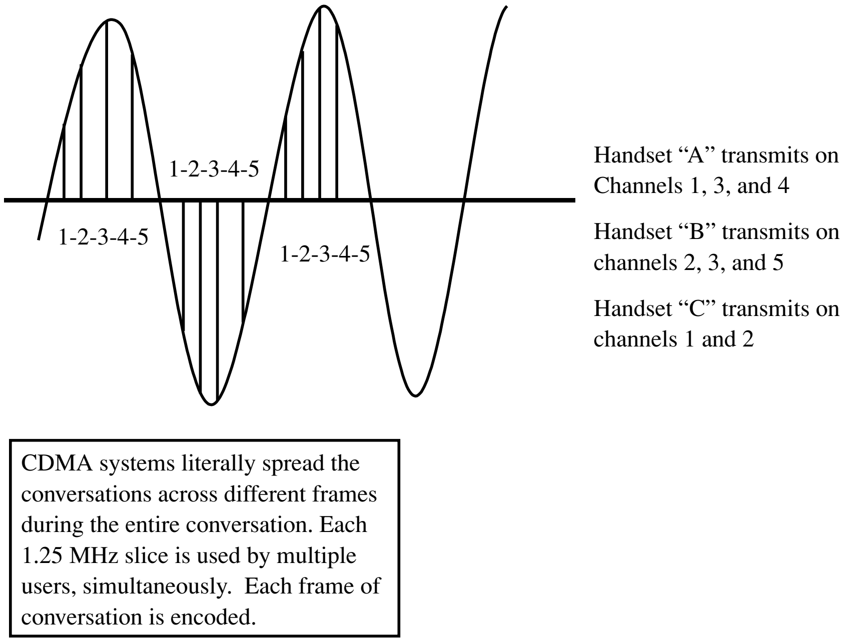

FIGURE 5.10 CDMA Waveform

distinct (logical) channels that are all uniquely PN coded. The encoded signals are spread in a near-random fashion across a 1.25-MHz slice; the receivers maintain coding reference patterns called masks. The masks are used to decode the signals. A CDMA system is more appropriately described in terms of bits. Remember that 64 channels comprise the 1.25-MHz slice. Each slice is capable of supporting multiple users simultaneously because of special encoding schemes. Each user's voice conversation requires about 3.8 kbps. The data rate for a human voice can be varied, albeit with some effect on voice quality. The digital signals are encoded in a fashion that ends up producing "chips." Approximately 134–536 chips are needed to produce one bit of information. Given all the spectrum sharing and small bits and chips of information being managed per user, one would expect the signal to sound like a lot of garbled noise.

The reason it does not is that CDMA was designed with what engineers call "chip collisions" in mind. Nothing can be so precisely managed that collisions of information do not occur on the reverse channel, because so many people are using the same frequency channel simultaneously. Frequency reuse solves this problem.

Frequency reuse in an AMPS, TDMA, and GSM system is a planned function. Frequencies are reused from cell site to cell site with care taken not to have adjacent cell sectors using the same set of frequencies. In the case of CDMA, one can theoretically reuse frequencies within the same cell as well as between cell sites, because each conversation is uniquely encoded. When signal collisions occur, the area in which the collisions happen reduces its capacity. However, in large-scale systems in commercial operations, frequency planning reduces collisions. Furthermore, care is taken to engineer the cell sites properly so that power emissions from one tower do not overwhelm another cell site. The potential capabilities of CDMA seem impressive, but there is one downside that comes to the mind of the businessman running the CDMA system: the level of highly skilled (and expensive) engineering talent needed to run a CDMA system because many design parameters to track and monitor. Figure 5.11 illustrates this concept.

The second attribute of CDMA is power control. Unlike TDMA and GSM, where power control is more of an issue of maintaining battery life in an idle state, CDMA power control is concerned with reducing overall radio signal interference. Power control in a CDMA system occurs in real time. As one moves closer to the cell site managing the call, the lower the transmitted power is out of the handset to the base station. CDMA signals received at the base station must be at nearly the same power level in order to reduce the effect of signal interference. If a handset were to transmit at a power level so high that its received signal overwhelms all other signals received at the base station, the effect would be catastrophic to all users at that base station.

Assume that a mobile device moves away from a base station. As it does so, the signal received at the base station gets weaker. The base station and mobile unit are in communica-

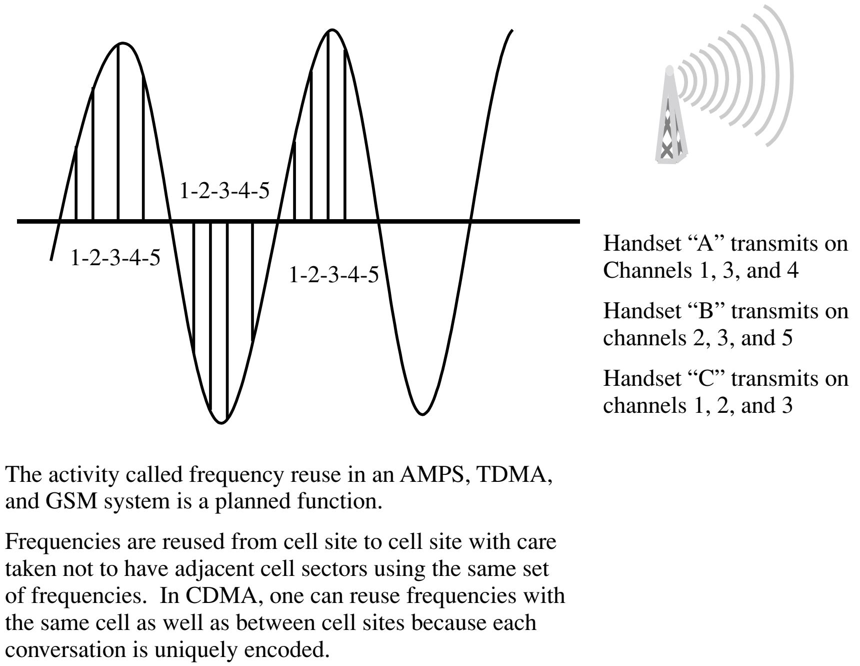

FIGURE 5.11 CDMA Frequency Reuse

tion with each other; the base station informs the handset to begin increasing transmitted power until it reaches the appropriate level. As the mobile unit moves closer to the base station, the received signal becomes stronger. In this scenario, if the mobile device is not instructed to power-down the signal it is transmitting, it will overwhelm the other handsets that are transmitting; the result will be that calls do not get through. Therefore, as the mobile unit moves closer to the base station, the base station instructs the handset to reduce the transmitted power levels. Figure 5.12 is an illustration of power control.

This is not a textbook on radio. However, I will cover two more unique attributes of CDMA, soft handoff and soft capacity. Soft capacity is a condition in which a CDMA system can operate in an overcapacity mode. As the signal interference increases, the quality of voice decreases. This is due to the noise that can be generated by having too many subscribers in an area. Effectively, one is reducing the capacity of the system.

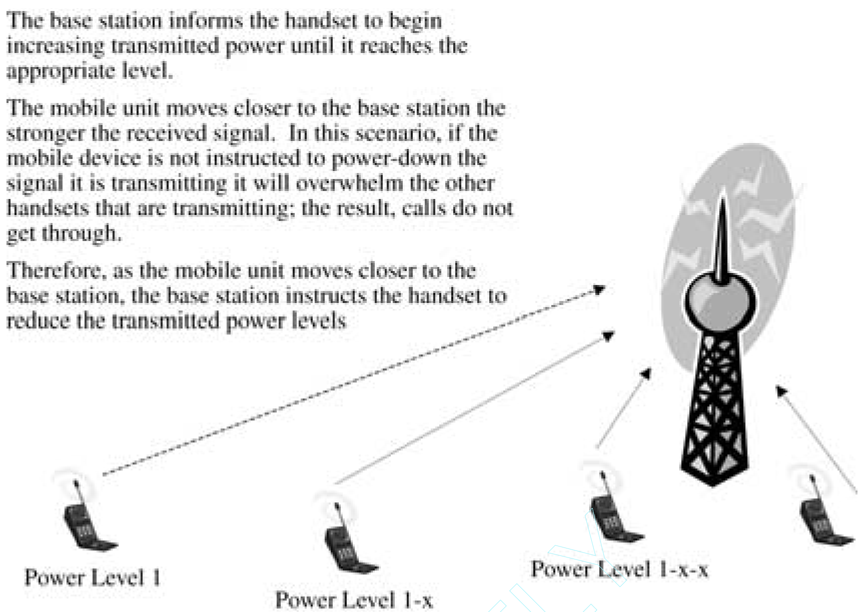

FIGURE 5.12 CDMA Power Control

However, depending on how the carrier engineers the system, a reduction in voice quality might be acceptable.

Soft handoff is unique to CDMA. A mobile user makes a call in a particular cell site. The base station monitors the handset as it is moving and makes a list of pilot channels (control channels) that are potential candidates for handoff. This list is transmitted to the mobile handset. The handset is also measuring signal strength from the candidate cell sites while still engaged in a call. When the signal strength of a candidate cell site reaches a certain level, the mobile handset then requests simultaneous transmission from the candidate cell site. The overall system then instructs the candidate cell site (we will call it cell site B) and the original cell site (we will call it cell site A) to transmit the call to the handset simultaneously. The mobile handset continues to decode both signals, using only the channel with the best signal quality. When the signal strength of the original cell site (cell site A) drops below a preset threshold, the handset releases the call from cell site A. Figure 5.13 illustrates soft handoff.

3G WIRELESS SERVICE IMPLEMENTATIONS

TDMA, GSM, and CDMA are the core technologies of the various 3G implementations under investigation and currently being prepared for implementation. The previous sections were intended to give you a high-level understanding of the core technologies. The reason there are so many different radio technologies is because of competition. Despite the FCC's wish for interoperability, this will not happen unless there are financial incentives. In any country, carriers run their businesses in order to generate profit. Why would carriers support interoperability unless there is roaming revenue involved? Furthermore, any interoperability that takes place will be between the same technologies, the only difference being that different carriers are using them. As part of the ongoing effort to be competitive, each radio technology has taken a different approach to providing wireless broadband.

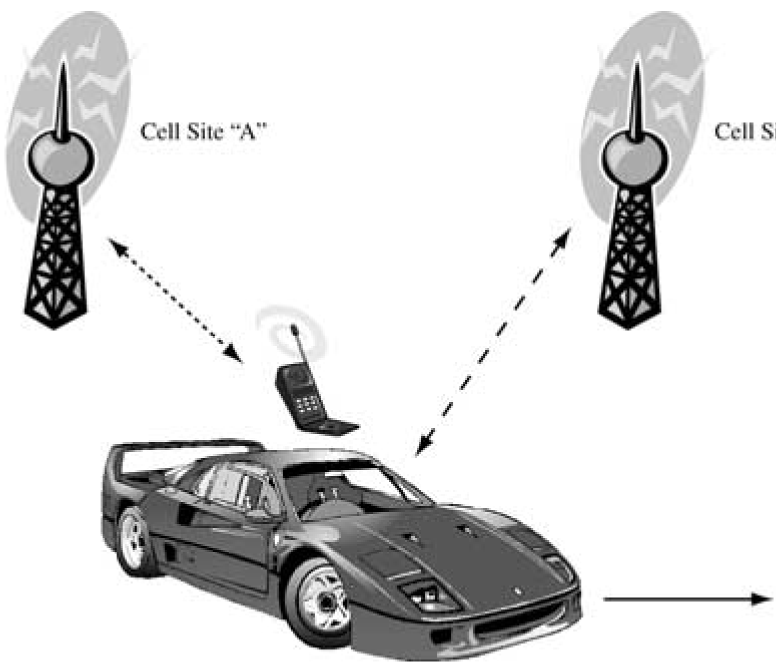

FIGURE 5.13 Soft Handoff

Some of the wireless broadband services being developed and under consideration for deployment are:

- High-Speed Circuit Switched Data (HSCD)
- General Packet Radio Service (GPRS)
- Enhanced Data Rates for GSM Evolution (EDGE)
- Wideband CDMA
- CDMA2000

The wireless services above can be described as more than just services. They are enhancements to the core radio technologies supporting cellular and PCS systems worldwide. They are the supporting/underlying radio technologies for the wireless broadband services that carriers are hoping to provide. The following subsections will briefly describe the wireless services listed.

Note that HSCD, GPRS, and EDGE are considered by many engineers in the technical community as 2.5G technologies, part of the evolutionary path to 3G. For the purposes of this book, given the way marketing organizations work, it is very possible a carrier will not even bother telling a subscriber if one technology is 3G or not. The subscriber typically does not even care what version of technology is being used. In the end it is all in the marketing.

HIGH-SPEED CIRCUIT SWITCHED DATA (HSCD)

HSCD is a service used by GSM service providers, but the deployment of HSCD has been limited because of the advent of other technologies. HSCD is capable of supporting data speeds of 28.8–56 kbps. Like GSM, HSCD uses time division multiplexing to support multiple users. HSCD combines two to four of the GSM time slots (there are a total of eight slots per GSM channel). Therefore, HSCD uses no more than half the number of time slots per frame that GSM uses for normal voice operations. HSCD is a minor modification to the GSM radio schema. HSCD is considered by GSM carriers to be an interim step.

GENERAL PACKET RADIO SERVICE (GPRS)

GPRS is also an interim step toward 3G. However, GPRS is considered more robust than HSCD. Most GSM carriers have held off deployment of HSCD in order to deploy GPRS.

GPRS combines up to all eight of the available GSM time slots to support Internet Protocol (IP)-based packet data speeds up to a maximum of 160 kbps. GSM carriers have been experimenting with a number of different configurations prior to commercial service. (There is always a need to understand how flexible a technology is in order to determine how to best deploy the technology for commercial service.) The proposed configurations either use only four time slots or use all eight of the time slots.

By using only four of the eight time slots, GPRS actually uses four time slots for the downlink and one for the uplink. The downlink refers to the direction of travel for the data. In the satellite world, a downlink refers to the data transmitted from the satellite to the ground station. In the case of GPRS, downlink refers to data from the base station to the handset. The downlink supports data rates up to 80 kbps. The uplink supports data rates up to 20 kbps.

Using all eight time slots, one would be using eight time slots for the downlink and one for the uplink. The downlink then supports data rates up to 160 kbps. The uplink then supports data rates up to 20 kbps. Multiple users can share one time slot or all eight time slots, or a single user could use all the time slots.

GPRS is envisioned to support X.25, IP-based services, and bursty data applications. Bursty data covers Web browsing, e-mail, and push technologies. Push technology refers to the way users had originally interacted with the World Wide Web: Instead of users looking for information on the Internet, information providers seek out users through automatic e-mail address registration on a Web site or because a user registered to get information. Push technology supports solicited and unsolicited information techniques.

Both HSCD and GPRS are capable of enabling users to use radio capacity when transmitting or receiving data. In this way capacity is not wasted on idle time. Briefly, GPRS is envisioned to be implemented over the existing GSM networks, although it can be implemented as a standalone network. It will be far more cost effective if GPRS technology is implemented as an overlay to complement and enhance an existing GSM network. GPRS requires its own functional network elements and essentially its own backbone network. GPRS data packets are transmitted from the base station over the GPRS backbone network or the existing GSM backbone network. Serving nodes are used to support a variety of resource management functions, path management, security, network connectivity, connectivity to the GSM network to collect user profile and routing information, and charging record data collection. The Gateway GPRS Support Node (GGSN) provides interconnection to other networks. The Serving GPRS Support Node (SGSN) tracks the location of the mobile units and provides access to the database resources of the GSM network or other databases. Therefore, the SGSN can provide mobility management, security, charging record data collection, routing management, and path management. Implementations of GPRS can have SGSNs distributed throughout the network. Multiple base stations can be interconnected to the SGSN.

Figure 5.14 illustrates the GPRS network configuration as standardized by the International Telecommunications Union (ITU).

ENHANCED DATA RATES FOR GSM EVOLUTION (EDGE)

EDGE is a step beyond GPRS. It represents the ultimate 3G goal for TDMA and GSM carriers. The industry considers EGDE to be that 3G technology that the TDMA and GSM carriers have been seeking. EDGE is envisioned to support data rates as high as 384 kbps on an internetwork basis (network-to-network connectivity), and 2 Mbps for local area network basis and Internet access (via the IP protocol). EDGE was originally developed by the GSM carrier community. EDGE is so conceptually appealing that the TDMA carrier community has adapted it to support radio technology. The challenge for TDMA carriers and vendors was to adapt this technology,

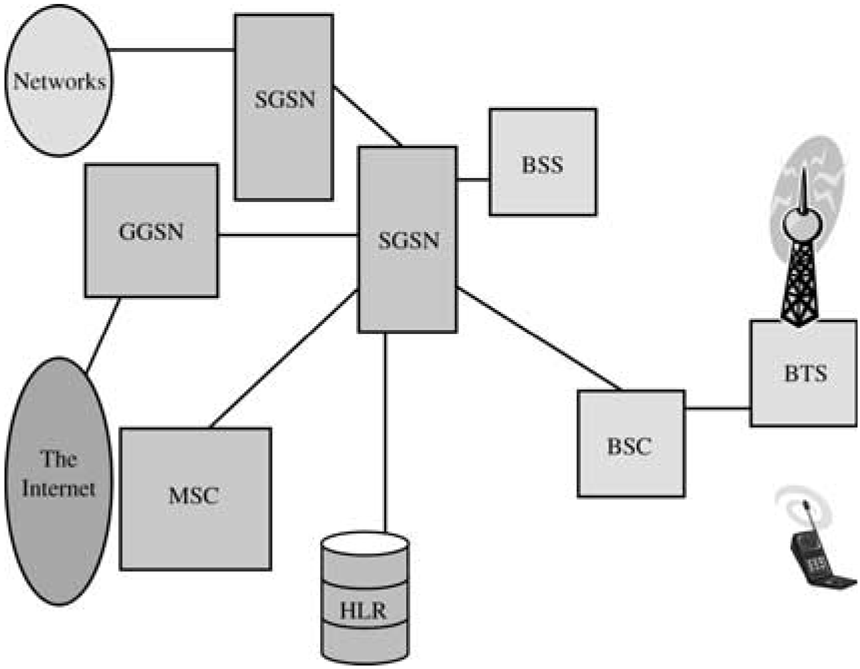

FIGURE 5.14 GPRS Network Configuration

intended to support 200-KHz channels, to support a radio technology that uses 30-KHz channels. In order to accomplish this task TDMA carriers have to do one of three things:

- Adapt IS-136 TDMA to support EDGE
- Adapt EDGE to support IS-136 TDMA
- Switch out the TDMA networks for GSM network technology

It is obvious to the most casual observer that carriers will not spend any money to adapt IS-136 to work with EDGE; there might be some minor interface modifications but nothing major will occur.

What is occurring are modifications to EDGE. The EDGE acronym has been recently retooled to mean Enhanced Data Rates for GSM and TDMA/IS-136 Evolution. The EDGE air interface was modified to function within the TDMA air interface. EDGE will function differently in TDMA than it would in a GSM network. For instance, frequency reuse patterns will be different in the TDMA EDGE network and the GSM EDGE network. Further, TDMA signal strength will be measured on the TDMA digital control channel, while GSM signal strength will be measured on the GSM carrier that is transmitting the broadcast control channel. TDMA proposed changes are the installation of radios capable of transmitting in 200-KHz channels.

The idea of a TDMA carrier's switching its network for a GSM network is not that far fetched. AT&T Wireless and Cingular have publicly announced their intentions (as of the second quarter of 2001) to migrate their networks to GSM. The next evolution of GSM is called Wideband CDMA, which is not compatible with TDMA. (TDMA standards are not getting the kind of intense attention that GSM is getting in the standards arena.) Therefore if one were to consider future enhancements, the need to meet commercial market needs, and future vendor support (there are far more carriers supporting GSM), a switch out of the network is not unreasonable.

Figure 5.15 is an illustration of an EDGE network. Note that the GPRS network elements can be reused.

WIDEBAND CDMA

Wideband Code Division Multiple Access (Wideband CDMA or WCDMA) is based on CDMA technology, but it is not IS-95 CDMA. WCDMA is an evolution of GSM, being developed under the auspices of the International Telecommunications Union (ITU), the European standards body that facilitates the creation of European telecommunications standards. WCDMA comes in two flavors: time division duplex (TDD) and frequency division duplex (FDD). FDD is a method of achieving full duplex communications. FDD supports communications in forward and reverse directions as separate and equal frequency slices. TDD divides the spectrum into multiple time slots. TDD supports communications in forward and reverse directions on separate but equal channels and time slots. WCDMA supports data speed up to 384 kbps for wide area coverage, and data speeds as high as 2 Mbps for local cov-

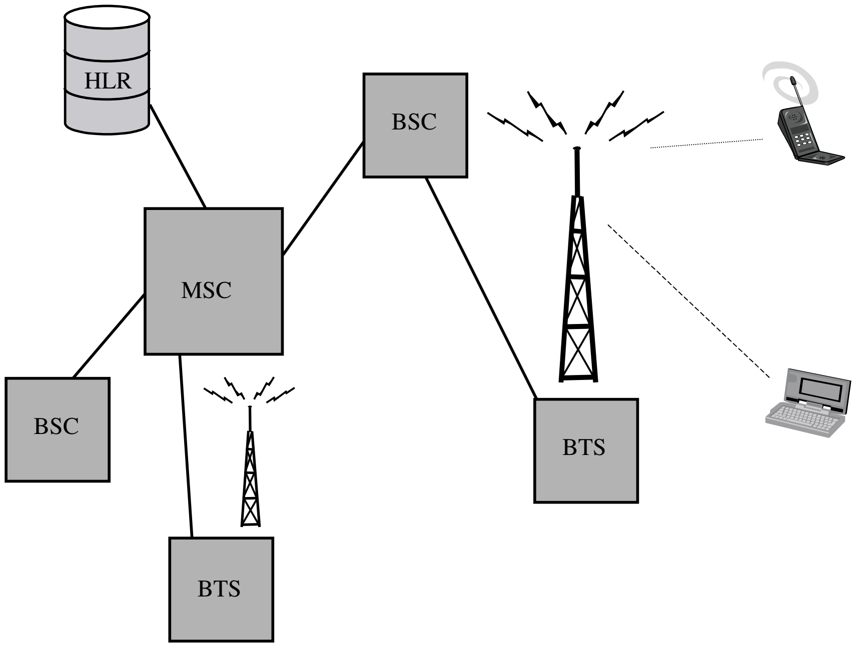

FIGURE 5.15 EDGE Network

erage (same cell site mobility), flexibility, and variable data rates. The frame size is 10 ms (10 milliseconds) long and the chip rate is 3.84 Mchips per second.

Figure 5.16 is an illustration of the WCDMA network. Note that the network integrates wireless and mobile IP.

The WCDMA network is comprised of a number of functionalities found in the GSM, GPRS, and EDGE networks, rolled up to create the network shown in Figure 5.16. The WCDMA network architecture contains the following elements:

- *Home Agent (HA).* A router that resides in the home network. The HA supports the transmission of IP datagrams to other routers or another agent. The HA may reside in a home based Internet Service Provider's (ISP's) network.
- *Foreign Agent (FA).* A router that resides in a roaming network.
- *Home Location Register (HLR).* A standard cellular and PCS carrier database that contains all user profile information and supporting routing information.

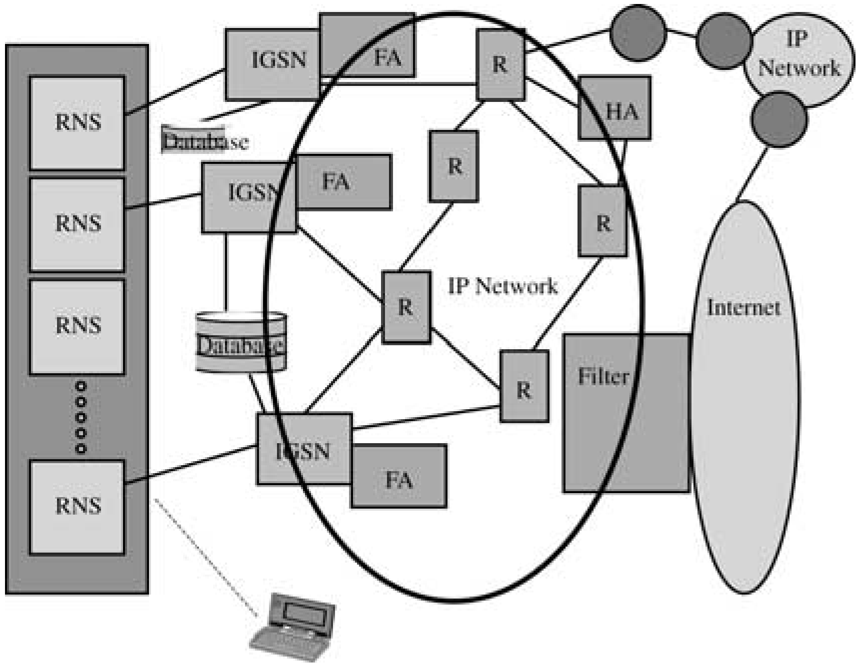

FIGURE 5.16 WCDMA Network

- *Authentication Center (AC).* A standard cellular and PCS carrier database that contains information to authenticate a user.
- *Radio Network Subsystem (RNS).* A collection of a base station and base station controllers. A base station controller manages multiple base stations in a GSM network. The base station controller is an additional layer of resource management.
- *Internet GPRS Support Node (IGSN).* Combines the functions of the serving SGSN and GGSN. The IGSN also serves to connect the radio network to the IP network.

WCDMA is supported by the ITU and is currently competing with CDMA2000 in the 3G marketplace.

CODE DIVISION MULTIPLE ACCESS 2000 (CDMA2000)

CDMA2000 is the 3G technology evolution of IS-95 CDMA. CDMA2000 and WCDMA are not compatible; even though there are attempts by standards groups to harmonize the standards to ensure bidirectional compatibility, the final commercial harmonized products will only appear in the marketplace if carriers pay for it.

CDMA2000 supports the following capabilities:

- N chip rates of N (= 1, 3, 6, 9, 12) Mchips per second × 1.2288, with each chip rate set corresponding to different radio channel bandwidths of N MHz x 1.25.
- 0 or 1 supplemental code channels per service at 9.6 kbps to 2Mbps.
- Frame lengths of 5, 10, 20, 40, and 80 milliseconds (ms).

The CDMA2000 network configuration is illustrated in Figure 5.17. Note that the functional network elements are different from those of the WCDMA network. The CDMA2000 network elements include:

- *Home Agent (HA).* A router that resides in the home network. The HA supports the transmission of IP datagrams to other routers or another agent.
- *Foreign Agent (FA).* A router that resides in a roaming network.
- *Authentication Center (AC).* Authenticates the user.
- *Home Location Register (HLR).* A standard cellular and PCS carrier database that contains all user profile information and supporting routing information.
- *Visitor Location Register.* A standard cellular and PCS carrier database that contains information to authenticate a visiting or roaming user.
- *Packet Data Switching Node (PDSN).* The node that connects the radio network to the IP network.

The PDSN supports the mobile IP function as well as serving to connect the networks. It supports all mobile IP routing and communications to the HLR and VLR.

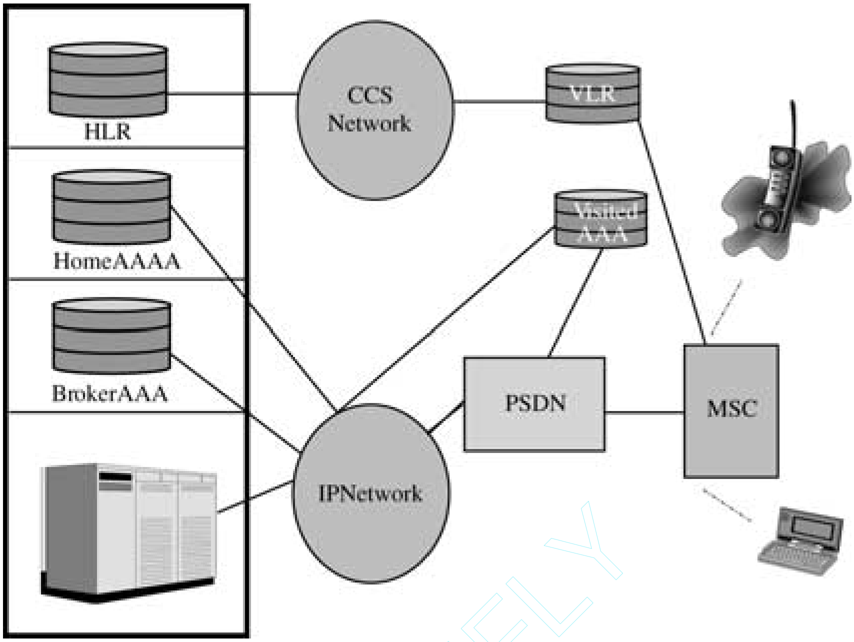

FIGURE 5.17 CDMA2000 Network Configuration

The fact that both CDMA2000 and WCDMA were based on radio technologies that were not compatible to begin with lies at the heart of incompatibility issues. There is industry-wide work to harmonize CDMA2000 and WCDMA, but this work focuses on compatibility via IP routing devices and IP protocol layers. The compatibility work can be successful if commercial and competitive interests do not take priority. The benefits of the Internet only took hold as quickly as they did because the Internet was open and free. The benefits of the Web will take hold in the marketplace faster if there is compatibility between these technologies. It is a simple and basic premise of product marketing and sales: make it easy to use and easy to find.

SATELLITE COMMUNICATIONS SYSTEMS

Satellite communications is an outgrowth of the quasiscientific, political space race. The first objects launched by mankind were satellites that emitted a simple repeating radio tone. The United States entered a space race with the Soviet Union in 1957 after the launching of the Soviet satellite Sputnik, the first artificial satellite launched into space.

Satellite communications was a natural outgrowth of this race. If man were to travel through space, work in orbit around the Earth, and land on the moon, a means of communicating between those on Earth and in space would be necessary. Essentially, satellite communications enables people to communicate over very large distances.

World War II drove the earliest development of satellite communications. The war caused the rapid development and growth of rocket and missile technology, which enabled the launching of artificial satellites. The war also heralded incredible growth in radio communications technology. Instead of carrying entertainment programs, radio during the war was used to transmit encoded messages either via manually developed codes or via specially encrypted signals. The war also drove the development and growth of microwave communications. Figure 5.18 is an illustration of the basic satellite system.

This chapter provides some detail on satellites. The satellite networks that orbit earth are entities and networks unto themselves. They can operate independently of terrestrial networks and can communicate directly with handsets without ever having to contact terrestrial networks. Further, the FCC classifies the satellite business in a unique regulatory arena.

Understanding how the satellite network systems work will give you additional insight and better understanding of issues that may arise in the future.

WHAT IS A SATELLITE?

Satellites have only a few basic but technologically complex parts: a satellite housing, a power system, an antenna system, a command and control system, a station-keeping system, and transponders. Satellites orbit the earth at varying altitudes. They present challenges that earth-based telecommunications systems do not face:

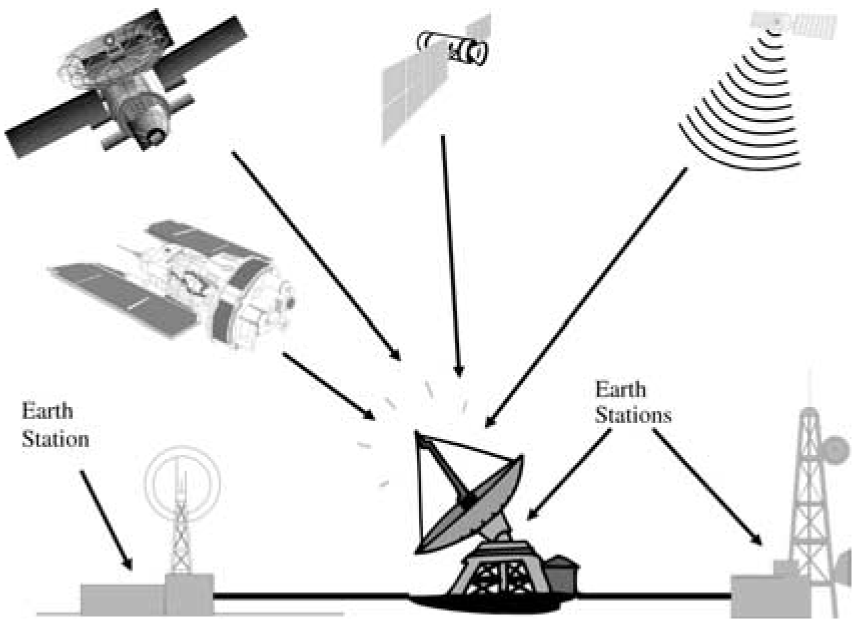

FIGURE 5.18 Satellite System

- Satellites continually operate in harsh environments, with no air, no atmospheric pressure. Temperatures approach absolute zero. In sunlight, satellites are subjected to high temperature extremes. In shadow, satellites are subjected to low temperature extremes. Satellites travel through space at high rates of speed and therefore are exposed to the dangers of collisions with objects in space: micrometeorites and manmade objects (lost tools, other satellites, and garbage).
- Satellites are subject to enormous physical stress during the launching and orbital placement phases.
- Satellites can only carry a limited power supply. The greater the power needs, the larger the power supply must be.
- Satellites need to be maintenance free. The space shuttle has enabled some satellites within the range of the shuttle to be repaired. However, satellites need to be designed and operated under the assumption that repair service will not be available.

- Satellites are expensive. Recent satellite launch failures have resulted in hundreds of millions of dollars in losses to satellite companies.

Satellite telecommunications has the following characteristics:

- The signal must travel very far; distances are on the order of thousands of miles. This can result in signal degradation.
- The signal cannot be regenerated for enhancement, as a terrestrial systems can via signal repeaters. When the signal arrives on earth it must be enhanced for transmission through a terrestrial network.
- The signal is transmitted through a medium filled with ambient noise and radiation. A ground-based system must be in place to interpret the signal received.
- An earth-based infrastructure must be maintained to ensure satellite space operation, orbital status, and systems health. This is similar to the terrestrial telecommunications systems' network operations centers. This is also known as a command and control center.

Figure 5.19 is an illustration of a satellite system.

SATELLITE SPECTRUM BANDS

Satellites operate in a number of high-frequency bands for a number of different applications. In the case of telecommunications, which includes radio, television, entertainment (satellite TV broadcasts), and public voice, satellites transmit in the following bands:

- L Band—1.5–2.5 GHz
- S Band—2.5–4 GHz
- C Band—3.4–7 GHz
- X Band—8–12 GHz
- Ku band—12–18 GHz

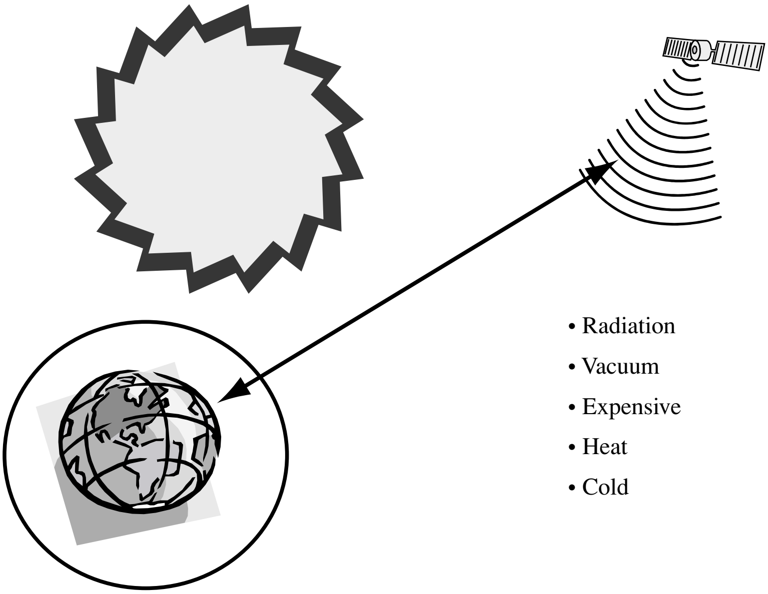

FIGURE 5.19 Satellite System Characteristics

- K Band—18–26 GHz
- Ka Band—26–40 GHz

These frequency bands support a multitude of communications services. Certain frequency ranges are shared by terrestrial telecommunications microwave systems. These microwave systems are used to support long-haul backbone telecommunications and other commercial applications. Sharing forces the satellite industry to deploy earth-based stations in a manner that minimizes interference. The following band classifications are managed in the United States by the Federal Communications Commission (FCC).

The L Band supports the following telecommunications services:

- Mobile Satellite Service (MSS). Low Earth Orbit (LEO) mobile satellite services
- Personal Communications Service (PCS)

- Ultra High Frequency (UHF) television
- Microwave links. These links are used to support terrestrial communications
- Local and state government applications. This may include law enforcement and public safety communications
- Very High Frequency (VHF) television. Typical broadcast television
- Cellular service

The S Band supports mobile satellite service and deep space research.

The C Band supports the following telecommunications services:

- Fixed Satellite Service (FSS). Includes deep space research and other types of government applications.
- Fixed service terrestrial microwave. This supports government applications.
- New types of terrestrial based telecommunications services such as location systems

The X Band supports the following telecommunications services:

- Military communications
- Fixed Satellite Service. Earth exploration and research; meteorological studies and research

The Ku Band supports the following telecommunications services:

- Satellite television. Direct broadcast to the home
- Broadcast satellite service
- Terrestrial microwave transmission. Long-haul applications and terrestrial linking

The K Band supports the following telecommunications services:

- Broadcast satellite service
- Fixed satellite service
- Terrestrial microwave transmission

The Ka Band supports the following telecommunications services:

- Fixed satellite service
- Terrestrial microwave transmissions
- New types of terrestrial mobile services (Local Multipoint Distribution Service [LMDS] uses this band)

Satellite systems can support analog and digital transmissions. Satellites multiplex signals using the following standard telecommunications techniques:

- *Frequency Division Multiple Access (FDMA).* A multiplexing technique in which a single radio transmission band is shared by multiple users. Each user is assigned a frequency within the band. FDMA is used in the analog cellular world. The users are effectively operating in a nonoverlapping channel. FDMA enables the cellular carrier to divide the total spectrum band into discrete channels.
- *Time Division Multiple Access (TDMA).* TDMA is a narrowband digital radio multiplexing technique in which the radio channel (not the band) is divided into time slots. Unlike FDMA, TDMA requires that the voice (or information) be digitized. This version of TDMA does not use the cellular multiplexing scheme.
- *Code Division Multiple Access (CDMA).* CDMA is a wideband digital radio technology. Satellites can support spectrum transmissions, but the CDMA supported by satellite systems is not the same as the version used by terrestrial cellular systems.

SATELLITE CLASSIFICATIONS

There are several different types of satellites. The general classes are:

- *Scientific.* Weather, environmental, cartography, and stellar observation
- *Communications.* Commercial radio, broadcast television, direct satellite television, cable television support, public voice, data, and video
- *Military or Government.* Various applications.

Figure 5.20 illustrates the satellite classifications.

Each of these classifications can be further subdivided into orbit types. The orbit classes have an impact on the way in which satellite networks are configured and the way in which services are provided. Figure 5.21 illustrates the orbit classes.

- *Low Earth Orbit (LEO).* Orbital altitude of 400–900 kilometers.
- *Medium Earth Orbit (MEO).* Orbital altitude of 5,000–12,000 kilometers.
- *Geosynchronous Orbit (GEO).* Orbital altitude of 35,800 kilometers.

OTHER SATELLITE CLASSIFICATIONS

The Federal Communications Commission (FCC) has created additional classifications for United States commercial and private satellite systems. These are used for regulatory purposes. The satellite industry is categorized and labeled, as is the rest of the public telecommunications industry. The classifications are:

- *Fixed Satellite Service (FSS).* This is a satellite industry term used to describe telecommunications services that are not mobile or broadcast. This classification applies to satellites that support scientific research endeavors.

FIGURE 5.20 Satellite Classifications

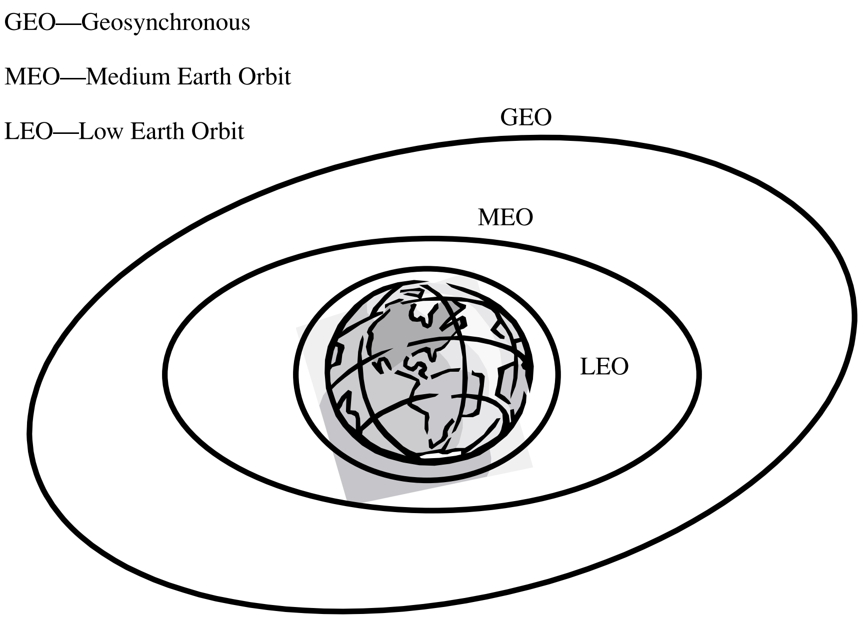

FIGURE 5.21 Satellite Orbit Classifications

- *Mobile Satellite Service (MSS).* This is a satellite industry term used to describe struggling, new LEO-supported mobile telecommunications service.
- *Broadcast Satellite Service (BSS).* This is an industry term used to describe the direct broadcast of information to the home—a direct satellite service. Satellite television is a common example.

SATELLITE SIGNALING APPLICATIONS

All satellite transmissions are broadband transmissions. When we think of satellite services, we typically thinks of standalone satellite services like direct broadcast satellite TV, weather satellites, satellite phones, and satellites used for scientific research and military communications. Except for direct broadcast satellite TV, none of these other services is explicitly observed or used by the everyday average subscriber. The subscriber may be the beneficiary of these satellite capabilities but these services are truly not subscriber services. Subscriber services include services such as common channel signaling–based services, voice mail, fax mail, call forwarding, caller identification, and call waiting.

Satellite communications is particularly well-suited for graphics-heavy data. It is also more cost effective than a T-1 for running business applications involving weekly or daily downloads of large files. The problem with satellite access is throughput. Rates vary but tend to top out around 400 kbps. The rate is high but it could be higher. Data compression helps. More important, most satellite technologies are broadcast-only—users need a modem for uploads. The following is a list of standardized satellite services and capabilities currently being provided by this segment of the telecommunications industry.

There are a number of space radio communications services:

- *Fixed satellite service.* This addresses communication between earth stations at specified fixed points via one or more satellites (e.g., Intelsat).

- *Mobile satellite services.* This provides communication between mobile earth stations and one or more space stations, or between mobile earth stations via one or more space stations. Earth stations can be situated onboard ships, onboard aircraft, and onboard terrestrial vehicles. This service may also be used to detect and locate emergency signals from people in distress. This has been expanded to include LEO mobile handset satellite services.
- *Broadcasting satellite service.* This allows sound and visuals to be received by individuals or communications via satellite.
- *Earth exploration satellite service.* This allows observation of the earth for various purposes, such as atmospheric and geological study.
- *Space research service.* Spacecraft are used for scientific or technical research.
- *Space operation service.* This is concerned exclusively with the operation of spacecraft.
- *Radio determination satellite service.* This is for the purpose of determining the position and velocity of an object using one or more space stations.
- *Amateur satellite service.* This is used by radio amateurs carrying out technical investigation and learning about intercommunications.
- *Intersatellite service.* This provides links between artificial earth satellites.

All of these services may implement wireless broadband. The industry is moving toward using the Ka-band because it is available and because small consumer antennas can be used.

SATELLITE WIRELESS BROADBAND

Satellite wireless broadband systems have been around for years, supporting the following kinds of broadband services since satellite communications' commercial inception:

- *Entertainment.* Includes television and radio programming. Television programming is the most prevalent form of broadband service today.
- *Education.* Includes distance learning and research.
- *Data transmission.* Includes data transmission to support businesses, financial transactions, and video.
- *Public telecommunications.* Includes wireline, cellular, PCS, paging, Internet access, and other types of wireless telecommunications.

Recently satellite networks have been called upon to support the Internet.

As I have noted, broadband and the Internet are inextricably linked. Broadband capabilities are the key to opening up the Internet bottleneck. Whereas the local loop has traditionally been the bottleneck in wireline broadband access to the Internet, satellite broadcasting can be sent directly to the user via rooftop satellite dishes, like those used in direct satellite television broadcasting.

SATELLITE INTERNET ISSUES

The challenges for satellite communications providers are implementation and signaling related. From an implementation perspective, coverage can be a problem. From a signaling perspective, transmitting the TCP/IP (Transmission Control Protocol/Internet Protocol) suite over a satellite system may be an issue from a security and routing standpoint. We will address these issues in the following subsections.

Internet over satellite is already in commercial operation. Satellite Internet systems are providing service in Asia, which include Web browsing and data transmission. The same carriers are also using their own authentication and encryption schemes. These security and routing schemas used may be proprietary, but they work.

COVERAGE. Satellite transmissions can be accomplished via direct broadcast to the user or to an earth station that is directly interconnected into a wireline network. In the direct broadcast scenario, the satellite system must be capable of covering large areas of terrain.

The typical example for wide area distribution of a satellite signal is the distribution of television signals in a multipoint/multicast manner, where a few terrestrial locations serve as transmission centers to multiple locations. Figure 5.22 is an illustration of this type of distribution mechanism.

Multicast/multipoint distribution of information is a cost-effective way of communicating information to multiple locations. However, the problem is that an earth station can serve as a bottleneck. This terrestrial bottleneck is not under the control of the satellite companies, but rather, that of some other carrier. The only way around the bottleneck issue is through direct broadcast.

SIGNALING ISSUES. Satellite transmission of a TCP/IP signal has a number of technical and implementation issues. These issues include:

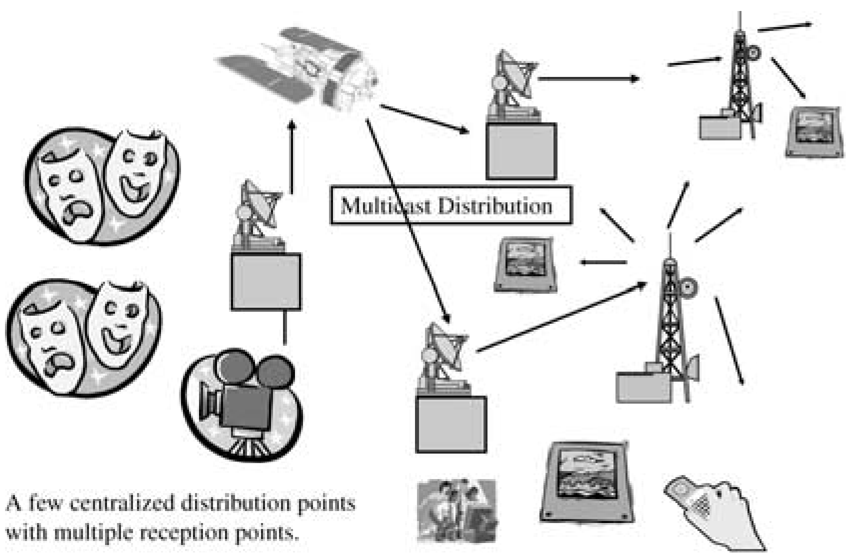

FIGURE 5.22 Satellite Signal Multicast/Multipoint Distribution

- Startup and acquisition of satellite and earth stations
- Bandwidth support
- Network management procedures
- Security
- Quality of service
- Signaling support of TCP/IP and other types of signaling
- Routing

Satellite systems utilize a slow-start procedure to power up and acquire ground (earth) stations. This procedure is an operational reality and could impede an Internet transaction. Memory buffering of data may overcome any delay issues. Other issues are questions of whether or not satellite broadcast channels can accommodate hundreds of megabits of data transmission in both a bursty and continuous manner without causing congestion problems. Next, the congestion management procedures for a satellite system are different from those used in the Internet world, just as congestion management in a wireline voice world is different from that used in the Internet world. The satellite network will have the same issues as the traditional voice wireline networks.

Security algorithms are a necessity on the Internet. In a satellite network, transmission may be intercepted and recorded for later decoding. Security algorithms will need to be improved because if satellite support for the Internet is going to be via direct broadcast, it will be broadcast over a large area.

The quality of service (QoS) requirements for Internet use are categorized as "best effort." This means that the Internet Service Provider (ISP) makes its best effort to complete a connection between web sites. However, there are ISPs working toward the high-reliability standards that are used in voice networks. The requirements for voice are, in fact, more stringent than those for data.

Signaling support for the Internet is TCP/IP. The question is whether or not a satellite network can support the commercial traffic load of an ISP. This has yet to be explored in any long-term fashion. Furthermore, if the satellite system being used is simply transporting or serving as a backbone for another carrier that is an ISP, the ISP may be using ATM to support its multimedia applications. There is a question of whether or not the satellite system can support QoS requirements for a multimedia service or can support the types of media signaling protocols that may be used.

Routing will be an issue for Internet applications. The Internet supports packet routing, where packets of data travel through the network via different routes, eventually finding their way to the destination. Internet routing is the most dynamic routing schema in existence. Satellite systems need to be able to support this kind of routing schema and still maintain connectivity to the user and support to applications. Figure 5.23 is an illustration of the issues just outlined.

WIRELESS LOCAL LOOP (WLL)

WLL is wireless access to the home and business (the whole local loop). Wireless carriers envision this as a way of replacing

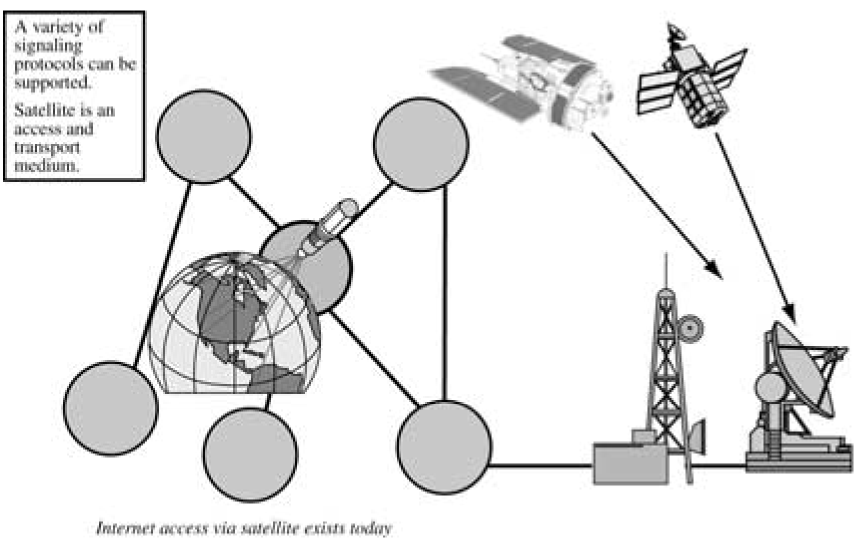

FIGURE 5.23 Satellite Signaling Issues

the fixed phone on the wall or the office telephone set. Wireless carriers seeking to compete with the wireline carriers are looking for ways to replace the fixed telephone through the use of various rate plans and combinations of intelligent call forwarding services, voice mail, and other services to penetrate the loop. Wireline carriers are also seeking ways of using wireless technology to maintain their control of the loop. Wireline carriers that have “sister” or ”sibling” wireless carriers are working with their sibling companies to find ways of keeping the subscribers within the “family of companies.”

A number of carriers have emerged as wireless local loop carriers using spectrum in the 24–34 GHz frequency bands. These wireless local loop carriers use line-of-sight (LOS) technologies to compete in the marketplace. (We will consider this further later in the chapter.)

In general, the technical challenges of WLL are:

- *Antenna placement*. Antenna placement is a challenge because a carrier needs to provide adequate coverage in a neighborhood so that dead spots are eliminated and relatively clear and noise-free transmission occurs. Carriers face uphill battles placing new 200-foot towers in communities. WLL poses a new challenge; placing antennas in residential neighborhoods without the benefit of towers. Rooftops or possibly telephone poles can be used. It is possible that the WLL carrier can establish a network of rooftop antennas throughout a community in order to achieve coverage. Telephone poles or even home rooftops are not optimal locations for antennas, because coverage is influenced by antenna height. New telephone poles are normally approximately 30–40 feet tall, but many communities have telephone poles dating back to the 1920s, and these are only about 20–25 feet tall. Many communities’ telephone poles are surrounded by tall foliage. Rooftops of homes are much lower than telephone poles, and homes are typically surrounded by foliage.
- *Coverage*. Coverage in this context refers to interference avoidance. This can be a challenge in a suburban community that has hundreds of homes in a one-square-mile neighbor-

hood. Each home must be capable of obtaining control and traffic channels with minimal blocking. In-building coverage can be achieved by cellular and PCS carriers by placing small antennas on the floors of buildings, referred to as picocells. Coverage, propagation, and multipath are still issues.

- *Frequency availability.* A wireline carrier needs spectrum to provide wireless access. Unlicensed spectrum is unacceptable.
- *Cell site capacity engineering.* Without good capacity engineering, the WLL carrier faces the possibility of cell site congestion.
- *Line of sight (LOS).* This is an issue for those wireless carriers using LOS technologies. These carriers have a slew of issues unique to their technology.
- *Radio technology selection.* The carrier, wireless or wireline, hoping to deploy a WLL network will need to select a radio technology. The radio technology will need to meet the following requirements:
  - High channel capacity
  - Subscriber service evolution
  - Privacy
  - Perceived wireline voice quality
  - Cells the size of less than one acre—picocells
  - Data services
  - Internet access

Figure 5.24 is a representation of the WLL implementation issues just discussed.

Cellular and PCS carriers deploying WLL systems face challenges unique to this particular wireless industry segment. Unlike typical wireless, WLL will be measured against the perceived quality of the wireline service. By holding itself up against the wireline industry, this type of WLL carrier faces an engineering challenge both technically and financially. However, cellular and PCS carriers that have deployed such systems can utilize their 3G technologies to bring broadband to the wireless local loop.

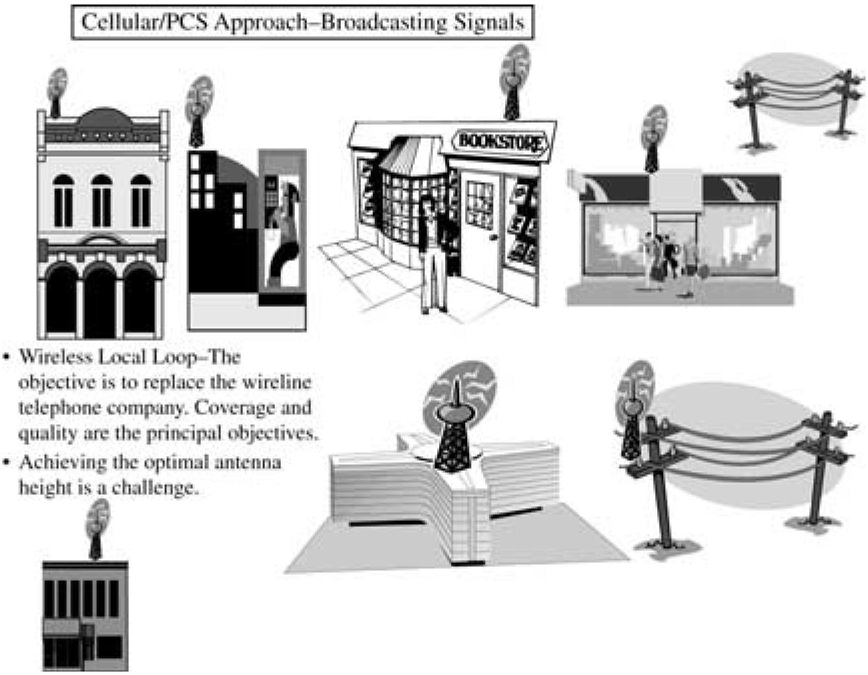

FIGURE 5.24 Wireless Local Loop—Implementation Issues

LOCAL MULTIPOINT DISTRIBUTION SERVICE (LMDS) AND LOCAL MULTIPOINT COMMUNICATIONS SERVICE (LMCS) CARRIERS

A type of wireless local loop carrier used to enter the wireless local loop market, is called Local Multipoint Distribution Service (LMDS) in the United States and Local Multipoint Communications Service (LMCS) in Canada. LMDS and LMCS carriers operate in the 24 GHz–34 GHz frequency bands. The spectrum had been occupied by the commercial industry and military, in both countries, therefore the licenses are scattered throughout the bands. However, the licenses cover huge tracts of spectrum; ranging from 150 MHz to 1.5 GHz, depending on the location of the license.

Given the size of the spectrum blocks, LMDS and LMCS carriers stand a better chance of providing wireless broadband services of a caliber greater than that of the non-LOS carriers. Note that at the frequencies at which the LMDS and LMCS carrier is operating, LOS transmission is the only viable option. Figure 5.25 is an illustration of a LMDS/LMCS carrier network configuration.

LMDS/LMCS RADIO IMPAIRMENTS

Radio signals at this frequency band encounter a number of radio frequency impairments. These impairments are path loss due to rain fade, signal blockage, multipath, and Doppler shift.

Path loss is the power loss a radio wave experiences as it moves away from the transmission source; the radio energy dissipates as it moves through free space and through objects. In the case of LMDS/LMCS, the radio energy is being transmitted at such small wavelengths that physical objects can completely block the signal. When radio energy wavelengths are on the order of millimeter wavelengths, physical object particulate density spacing is nearly equal to that of the wavelength, and total signal blocking and reflection will occur. With LOS technologies such as LMDS/LMCS, at certain power levels path loss will occur due to rain; hence the term rain fade.

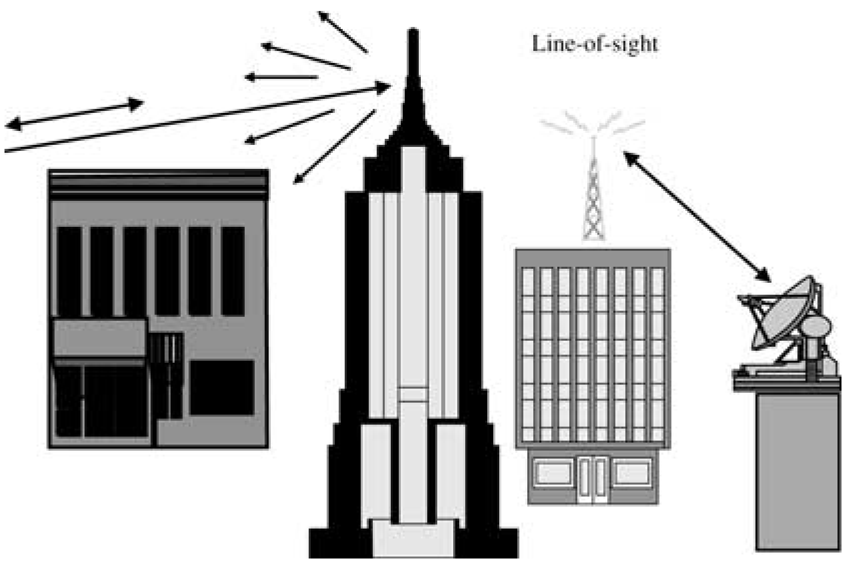

FIGURE 5.25 LMDS/LMCS Carrier Network

Multipath is a huge urban problem that occurs when a signal is moving through and around objects, so that copies of itself arrive at the destination point at different times. A radio signal can be likened to an ocean wavefront moving through air. As part of a wavefront hits an object one part continues to move toward the destination while the part hitting the object is either blocked or allowed to pass around it. The part that has passed around the object is moving just a little behind the unobstructed wavefront. A radio wavefront is either blocked or allowed to pass through the object and, as a result of passing through the material, the wavefront is essentially a copy of the signal. This obstructed radio signal has a reduced signal strength and will arrive after the partial but original signal has already arrived at the destination. Multipath can cause interference and confuse the receiver.

Doppler shift occurs when there is motion between the transmitter and the receiver and the motion causes a frequency shift that has an impact on the original signal or even causes more multipath troubles. One way of looking at Doppler shift is to consider the example of a train moving toward you as it blows its whistle. The pitch of the whistle will seem to rise as the train moves closer and the whistle will sound louder. However, as the train is moving away, the whistle sounds differently because the pitch (sharpness) decreases. A radio wave that has undergone a Doppler shift results in a wave that is half a wavelength out of phase from the original signal; this copy can cause interference.

LMDS and LMCS systems are also called millimeter wave systems because of the high frequencies and extremely small wavelengths at which they operate. In general, LMDS and LMCS systems can suffer radio propagation impairments due to the following (this assumes the systems are operating at safe power levels):

- Atmospheric gases—pollution, ozone, etc.
- Humidity
- Dust in the atmosphere
- Foliage

- Atmospheric heat
- Heat from buildings or obstacles near the path of transmission
- Rain
- Snow

There are engineering techniques to mitigate the challenges presented by these issues, such as repeaters or reflectors to bounce the signal around obstacles and to regenerate any degraded signals.

LMDS/LMCS SERVICES

LMDS/LMCS carrier services include all the voice, data, and Internet applications the industry has envisioned. Like satellite, LMDS/LMCS carriers can beam directly to a customer premise, building, or home wired with either fiber or T-1/E-1 facilities. An LMDS/LMCS carrier can avoid the bottleneck issues faced by other carriers.

The LMDS/LMCS carrier is designed to bypass the ILEC's local loop. If this is done appropriately, the LMDS/LMCS carrier will be able to provide streaming video and music to customers, with these services carried over the air using a TDMA or FDMA radio schema. Given the size of the bandwidth being used, capacity should not be an issue.

MULTICHANNEL MULTIPOINT DISTRIBUTION SERVICE (MMDS) CARRIERS

MMDS carriers are those line-of-sight carriers operating in the 2.1–2.7 GHz frequency bands. Until recently, these frequency bands had been used by wireless cable television companies.

Wireless cable TV is the layman's name for Multichannel Multipoint Distribution Service (MMDS). This type of cable TV is a fascinating combination of satellite transmission and reception and fixed transmission facilities. MMDS is a type of cable television system that offers its subscribers a mix of satellite channels by transmitting the programming over MMDS frequencies. Wireless cable uses Super High Frequency (SHF) channels to transmit satellite cable programming over the air instead of through overhead or underground wires. MMDS offers high bandwidth, but unfortunately, MMDS development in the area of interactive voice and video services has been limited. MMDS is an economical way of providing cable TV in high-operating–cost areas.

Today, MMDS is a potential way of providing Internet access and associated services. Think of Web-based television and you will see MMDS as another wireless broadband option.

Scrambled satellite cable programming is received at a central location where it is processed and fed into special transmitters located in various earth stations. The SHF transmitters distribute the programming throughout the coverage area. The signals are received by special antennas installed on subscribers' roofs, combined with the existing VHF and UHF channels from the subscribers' existing antenna, and distributed within the home or building through coaxial cable into a channel program selector located near the television set. This application combines satellite service in such a way that it embraces the benefits of satellite rather than treating it as a competitive technology—a good example of synergy between telecommunications business segments. Benefits of MMDS are:

- *Availability.* Wireless cable can be made available in areas of scattered population and other areas where it is too expensive to build a traditional cable station.
- *Affordability.* Due to the lower costs of building a wireless cable station, savings can be passed on to the subscribers.
- *Internet access.*
- *Broadband services* using high definition television (HDTV) sets.

Figure 5.26 is an illustration of the MMDS system.

Wireless cable operations may have as many as 33 channels of broadcast and cable programming. This, of course, depends on which channels are already used in your area. If you use digital compression you can squeeze in another 150 to

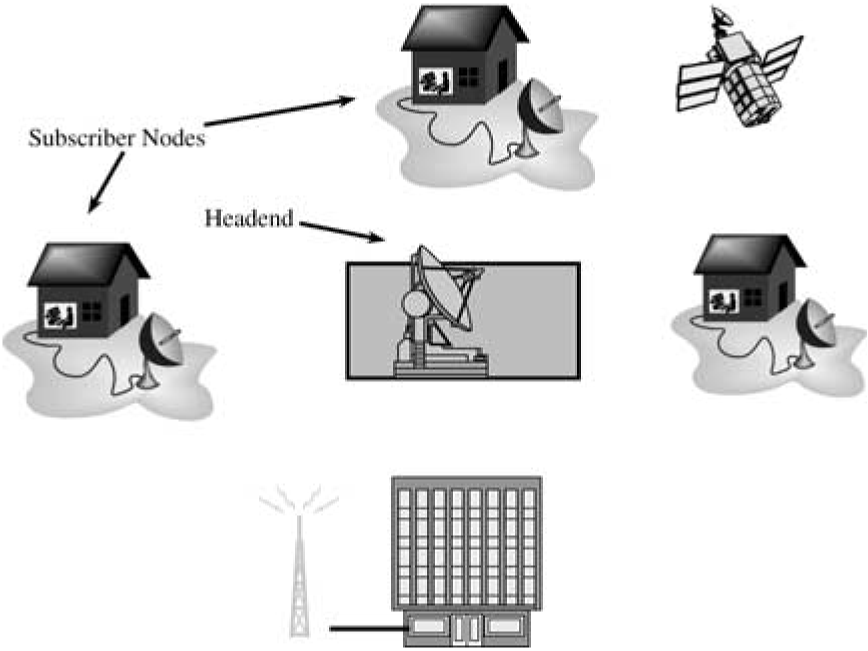

FIGURE 5.26 MMDS Configuration

300 channels. Wireless cable systems can carry any of the normal basic and premium cable television channels.

MMDS systems can achieve an optimal range of up to 25–30 miles. This depends largely on the terrain, transmitting power, both the transmitting and receiving equipment, and many other factors. In order to receive the signal, the transmitting and receiving antennas must be line of sight. Equipment requirements for the home are:

- MMDS antenna.
- *Cable down converter.* The cable television down converter is the set-top converter box. This box contains an addressable decoder and a VHF/UHF tuner built in. This gives the down converter the ability to tune in broadcast channels without having to use valuable MMDS channels.
- UHF and VHF antenna for normal broadcast channels.

SUMMARY

As I noted at the beginning of this chapter, wireless telecommunications broadband technologies support data at data rates greater than 14.4 kbps. Wireless broadband is supported by a multitude of technologies and provisioning implementations. Broadband wireless services can be provided by radio frequency (RF) technologies such as Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and Global Systems for Mobile Communications (GSM). Wireless broadband services can be provided by cellular and PCS carriers or even by line-of-sight (LOS) carriers. Some industry professionals claim that wireless broadband services refer to LOS systems only. However, I do not subscribe to that belief. The LOS carriers most commonly referred to in industry trade magazines are those classified as Local Multipoint Distribution Service (LMDS), Local Multipoint Communications Service (LMCS) or Multichannel Multipoint Distribution Service (MMDS) carriers.

This chapter is not intended to indicate a preference for one radio technology over another, but to give the reader a high-level view of the various wireless broadband technologies available.

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CHAPTER SIX

NETWORK SIGNALING FORMATS

Network signaling is the language by which service providers communicate with other service providers and by which service providers communicate with elements within their own network. A more technically precise definition would be that signaling is the exchange of information in a telecommunications network (public and private) that establishes and controls the connection of a call or a communication between subscribers or computing systems and also the transfer of subscriber, end-to-end, and management (subscriber and network) information.

This chapter will address the wireline or fixed network signaling protocols used to support network element communication and network connectivity. Radio technologies such as EDGE, 3G, TDMA, or CDMA are not network signaling protocols used to support network connectivity. Rather they support communications to their own subscribers. There must be a common network signaling protocol used to support communication between different networks. At this time the most popular network signaling protocols are:

- Multi-Frequency (MF)
- Signaling System 7 (SS7)

- Asynchronous Transfer Mode (ATM)
- Transmission Control Protocol/Internet Protocol (TCP/IP)
- Frame Relay

There are other types of signaling just as important. The following represents local loop signaling:

- *Address.* These signals convey call destination information or the digits dialed by the calling party. Types of address signaling include dial pulse and Dual-Tone Multi-Frequency (DTMF).
- *Supervisory.* This type of signaling indicates the status of the line or trunk, i.e., whether or not there is a busy (off hook) or idle (on hook) condition. Types of supervisory signaling in the landline telephony world include loop, reverse battery, and E&M.
- *Alerting.* These signals alert the user of an incoming call. This is the ringing the user hears, also known as power ringing in the landline world.
- *Call progress.* Call progress tones are the tones the calling party hears while making a call. They inform the calling party of the various events that occur during the course of the call.
- *Control.* Control signals are used for special auxiliary functions beyond a service provider's network. These signals communicate information that enables or disables certain types of calls. One example would be call barring.
- *Test.* Test signals are used by carrier personnel to check for network health and status.
- Subscriber/user initiated signaling.

These subcategories are largely associated with the traditional wireline telephone network. This network signaling is not state of the art, but is the dominant network signaling embedded in the largest network in North America and in most wireline networks around the globe. Multi-Frequency Signaling and Signaling System 7 (SS7) are the dominant forms in existence today and therefore deserve to be described in detail.

INTERSYSTEM SIGNALING (INTERNETWORK SIGNALING)

Descriptions of network signaling used to communicate between networks follow. The terms used, intersystem and internetwork, refer to the function of the network signaling. This signaling is not used to communicate directly to the user. Local loop address signaling is still largely DTMF-based.

DTMF is an intranetwork signaling protocol. Intersystem and internetwork signaling connects networks and switches; it does not support direct connection to the end user.

MULTI-FREQUENCY (MF) SIGNALING

MF signaling uses tone pulsing in the voice frequency range. Its telecommunications history begins in the wireline telephone world. MF signaling (tone pulsing) transmits digits by combining two of six frequencies. Each combination of tones represents a single digit. MF tones are pulsed in the voice frequency range, which means that the tones are sent over the talking path. MF signaling is known as in-band signaling. The voice information, the telephone call's control signaling, and the called telephone number are transmitted over the same physical transmission facility.

MF signaling utilizes tones in the 700–1,700 Hz range. When a MF tone is transmitted (representing a digit), two frequencies are sent simultaneously for each digit. They are not audible to the subscriber making the telephone call. Table 6.1 illustrates the MF signaling code.

Note that supplementary tones called KP and ST tones are also supported. KP stands for request for Key Pulsing Sender, which refers to the beginning of a pulsing sequence. ST stands for the completion of keying and the start of circuit operations; shorthand for this start tone is ST. There are additional frequency combinations used to support certain types of telephone calls. See Table 6.2.

TABLE 6.1 MF Signaling Tone and Digit Combinations

DIGITS	FREQUENCIES (HZ)
1	700+900
2	700+1100
3	900+1100
4	700+1300
5	900+1300
6	1100+1300
7	700+1500
8	900+1500
9	1100+1500
0	1300+1500
KP	1100+1700
ST	1500+1700

As you can see from the table, ten of the frequency combinations are used to support dialed digits 0 through 9. There are additional types of KP and ST tones, as Table 6.2 describes.

TABLE 6.2 Additional MF Signaling Tone and Digit Combinations

DIGITS	FREQUENCIES (HZ)
1	700+900
2	700+1100
3	900+1100
4	700+1300
5	900+1300
6	1100+1300
7	700+1500
8	900+1500
9	1100+1500
0	1300+1500
KP	1100+1700
ST	1500+1700
KP2 (ETSI)	1300+1700
ST2prime (ST'')	1300+1700
ST3prime (ST''')	700+1700
STprime (ST')	900+1700

The KP2 tone is used in non-North American telephone systems. The same frequency combination for KP2 is also used by ST2-prime tones for an operator services system. The ST-prime and ST3-prime tones are used to support operator services activities and coin telephone operations.

Most service providers are converting their respective networks to ones based on some form of common channel signaling. Common channel signaling can support broadband applications; MF cannot support any of the broadband services envisioned. Even though there are advantages to separating voice and control signaling, there are advantages and applications for MF signaling, too, because applications are all tone based and interswitch MF signaling is tone based.

- *POTS (Plain Old Telephone Service).* Remember that there are millions of people who just want to purchase basic voice services only. The challenge for all carriers is to increase revenue from this type of subscriber by selling services over and above basic voice.
- *Computer modems.* The modems in home computers and laptops convert digital information into tones (i.e., analog sine waves) that can be sent over a standard telephone transmission facility. (This does not cover computers using ISDN or other types of protocols.) The majority of the population has learned to live with slow-speed modem access. Would people like more speed? The answer is probably yes, but people tend to make do until something better comes along.
- *Operator services.* Inband interaction with automated menu systems is used by many carriers, like "keypad menus."
- *Directory assistance.* Inband interaction with automated menu systems is used by many carriers, like "keypad menus."
- *Noncaller identification numbering services.* Such services include call forwarding, switch-based voice mail, call waiting, and call hold (terminal support is needed).
- *Terminal-based services that support subscriber interaction via tones.* Customer-based voice mail systems are accessed and navigated by the user via the tones generated by touching the

keypad of the telephone device. These tones are called DTMF tones but are carried over MF trunks (transmission facilities). DTMF tones are the signaling tones between a customer's telephone set and the switch. DTMF is explained later in this chapter.

The disadvantage of MF is the fact that MF signaling cannot support the broadband applications that the industry envisions. MF is a signaling method that can continue to support a variety of services as long as the economic drivers to change the network do not exist. The broadband industry faces a number of challenges before telecommunications carriers and information media companies are willing to spend billions of dollars on a venture that may fail. This issue is covered in greater detail later in the book.

SIGNALING SYSTEM 7 (SS7)/COMMON CHANNEL SIGNALING 7 (CCS7)

SS7 is a Common Channel Signaling (CCS) protocol. It is an out-of-band signaling scheme and is the dominant form of CCS in North America. CCS7 is the dominant form of common channel signaling in Europe. The signaling schemes described in the preceding section are all circuit associated, in-band signaling. Whereas multi-frequency (MF) pulsing is tone based, SS7/CCS7 is actually a computer message–based signaling protocol. In MF pulsing, the signals used to set up facilities between the called and calling parties occur on the same physical path as that of the conversation. Under SS7/CCS7 signaling, the information associated with setting up the facility path for the conversation is different from the conversation path. There are not only new subscriber services but also network efficiencies enabled by SS7, which we will address later in this section.

Prior to SS7, in North America, there was Signaling System 6 (SS6) or CCIS 6 (as known to some) that supported toll (i.e., long distance) traffic in the predivestiture AT&T days. SS6 is a CCS protocol that supported 4.8 kbps transmissions and also represented the first packet data applications in the public telecommunications network. The development of SS7 enabled wireline carriers to increase data transmission speed to 56–64 kbps. SS7 also extended the strengths of common channel signaling to the user in the form of real-time subscriber controlled services and caller identification services.

The architecture shown in Figure 6.1 is associated with SS7/CCS7 systems.

SS7 BENEFITS

There are specific network benefits in deploying an SS7 network. These are not obvious to a subscriber but include:

- *Faster call setup.* Subscribers calling within a local calling area (e.g., the other side of a town or city, the other side of a

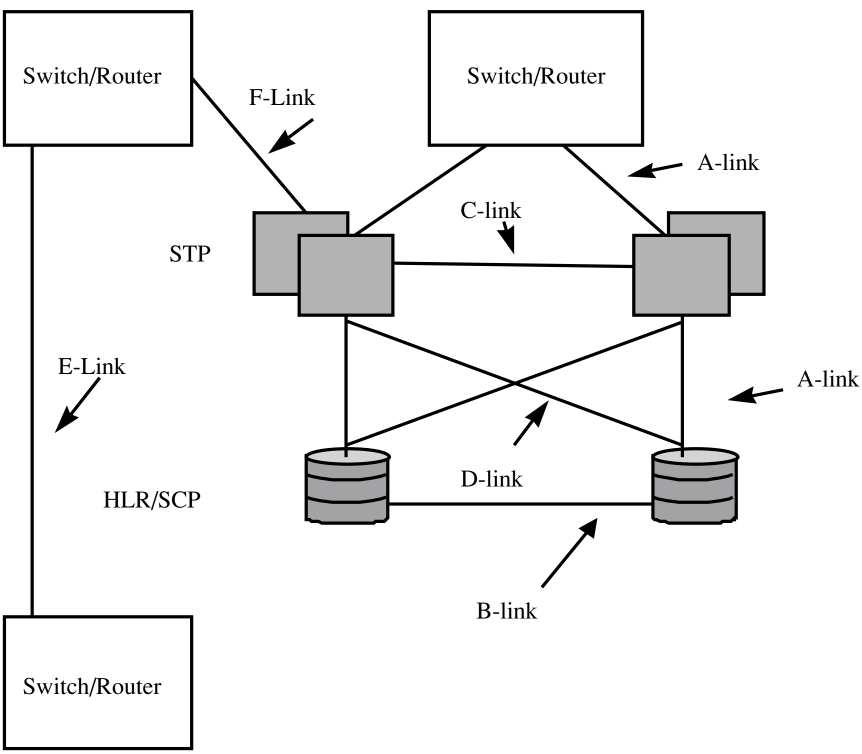

FIGURE 6.1 Signaling System 7/Common Channel Signaling 7

state) will not perceive an increase in the amount of time needed to establish a connection between subscribers. In the case of a coast-to-coast call, users can expect a 3–4 second decrease in call setup from the time the calling user enters the last digit to the time the calling user hears ringing on the telephone. (Users may not believe this but when you compares how long it took to hear audible ringing prior to the early 1980s call setup is much faster.)

- *Optimized use of transmission facilities.* Prior to SS7, end-to-end common channel signaling did not exist in the public telecommunications network. This lack meant that a transmission facility had to be set up physically between the originating point and the terminating point. In order to determine if the called subscriber was "on the line," the transmission facilities between the calling parties had to be completely set up; if the called party was "busy" the originating party's switch would be informed via "line status signaling tone" and the calling party would hear a busy tone. SS7 avoids this call setup scenario by enabling the carrier to look ahead via the data link, thereby avoiding the unnecessary and wasteful expenditure of time and resources in setting up transmission facilities across the nation.
- *Database querying and management.* Using databases in a wireline telephone environment existed prior to SS7. Databases stored customer service profile information, billing information, and internal carrier operation information. However, none of this information could be used to execute an activity in real-time fashion (at will, regardless of time). SS7 enabled the carrier to use all the aforementioned information to set up calls and even manage the network in real time. The real-time, information accessing and management nature of the SS7 network was considered a revolutionary event in some quarters of the wireline public telecommunications network engineering community; to others SS7 or out-of-band signaling was inevitable. Regardless of one's opinion on the nature of SS7's revolutionary or evolutionary nature, SS7 changed the way carriers provided services, the types of services, and how they managed their networks.

As revolutionary or evolutionary as SS7 is, there is a downside. The disadvantages or negative aspects of SS7 are:

- It requires two separate communications paths: one for the data link and the other for the voice or information content.
- It requires traffic engineering on two separate communications paths. The traffic engineer needs to understand that each of the two paths is carrying different types of data. One path may be voice, the other path call setup information. Voice and call setup data have different characteristics.
- It requires maintenance of two separate physical transmission networks, which means additional time and money on the part of the carrier.
- It has additional network elements to engineer, install, and maintain. These are the Signal Transfer Point (STP) and the Service Control Point (SCP).
- SS7 does not enable high-speed data. The maximum transmission speed of an SS7 data link is 56/64 kbps. As a high-speed data link, an SS7 link is a poor choice.
- SS7 does not support the new large bandwidth multimedia services that are envisioned.

Figure 6.2 highlights the attributes of SS7.

The next section addresses Asynchronous Transfer Mode (ATM), a high-speed, out-of-band signaling protocol that to some seemed the next evolutionary step in the growth of the public telecommunications network.

ASYNCHRONOUS TRANSFER MODE (ATM)

ATM is a broadband network protocol. It is a part of the larger set of broadband ISDN procedures standardized in the industry. ATM, however, can exist without ISDN. ATM receives a great deal of attention because it is considered to be the future of broadband and integrated data, voice, and video in the public

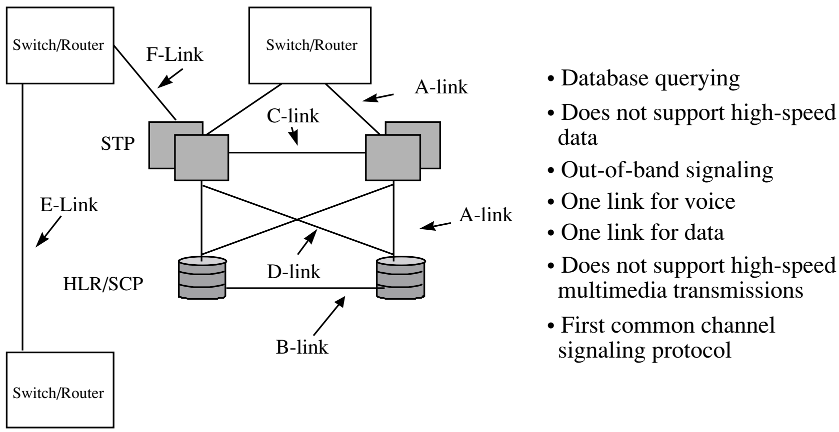

FIGURE 6.2 SS7 Attributes

telecommunications network. ATM is currently being deployed, but like so many of the network signaling protocols in use today, its development began in the days before the divestiture of the AT&T Bell System.

ATM was envisioned as a way of interconnecting ISDN customers. Since developing ATM is so complex, SS7 became the signaling network envisioned to interconnect ISDN customer groups.

ATM is a backbone signaling protocol designed to interconnect networks, using asynchronous transmission of signaling information. The public telecommunications network are mostly synchronous, however, and connection oriented. To deploy a network that did not support the most basic aspect of signaling transmission would mean a fundamental change in the way in which calls were transmitted, received, and processed.

For many, asynchronous transmission was simply too radical a change in the public telecommunications network. Any change in that network could result in costly change in every switching system in the network. The market and financial needs to drive more bandwidth in the network created an overwhelming wave of support to accelerate ATM development and deployment. ISDN no longer served as a driver for ATM; instead the general need to create value from a consumer and carrier perspectives drives ATM today.

ASYNCHRONOUS TRANSFER MODE (ATM) SIGNALING DESCRIPTION

ATM is a network signaling protocol developed in support of Broadband-ISDN (B-ISDN); it combines packet switching concepts with traditional switching concepts. ATM is one of a class of packet technologies that relays traffic via an address contained within the packet's header. ATM transports information by using very short fixed-length packets or cells. These *cells* are asynchronous time-division multiplexed. ATM is both connection oriented and connectionless oriented.

Packet switching is a connection-oriented method of information delivery in the network. A packet switch sends the information in packets of data. The information is disassembled into discrete packets of information or data. Each packet has a unique identification and carries its own destination address; therefore packets can travel through the network independently of each other. Packets of data travel to the final destination or termination point via different routes. Since packets travel different routes, the likelihood is high that the packets will arrive at the destination at different times and out of sequence.

Packet switching essentially establishes a virtual connection between the originating and terminating points. Since large files are broken down into packets of data, and the data is transported in this virtual manner, packet switching is an efficient way of transporting large data files between networks. Packet networks use the X.25 transport protocol. Since X.25 is a standardized industry protocol, both public and private packet switch networks can communicate with each other.

- *Connection oriented.* Connection-oriented calls are information transactions such as the typical voice call, ATM calls, Frame Relay calls, ISDN calls, packet-switched calls, and all circuit-switched calls. Connection-oriented calls are characterized by the following processes:
  - Call setup—includes request for circuit, acknowledgment of call receipt
  - Information, call, and data transmission

– Call teardown/release

- *Connectionless oriented.* Connectionless-oriented calls are information transactions that do not involve a formal acknowledgment of call completion, answer supervision, or circuit establishment. Delivery of the information is not guaranteed or reliable. Internet transmissions are connectionless transactions. Current efforts to have the Internet support multimedia and voice applications are leading to the implementation of formal acknowledgment message sets.

ATM combines the best of both packet switching and connectionless switching. ATM is like SS7, a backbone network signaling protocol designed to transmit information at high speeds. ATM has the potential of binding a network of networks into one virtual and integrated network. Why would anyone even think of applying ATM in such a manner?

ATM ADVANTAGES

There are good reasons for supporting ATM. In a world where there is a multiplicity of networks, ATM is a good candidate for integrating these networks and their services, including wireless networks and services. Its advantages include:

- *Granular control and network flexibility.* The processing of cells provides greater network control over routing, error control, flow control, copying, and assigning priorities. Note that in an ATM network, each cell can be assigned a delay or loss priority, therefore the service provider can exercise control over one traffic class relative to another class.
- *Dynamic bandwidth allocation.* ATM has the ability to allocate bandwidth dynamically to all types of cell traffic.
- *Service transparency.* ATM is service-application transparent. The cell size is a compromise between the short repetitive frames of voice and the long ones of data. Therefore ATM allows for mixing data, voice, and video within an application. ATM's granular control of cells allows the network to be customized to a specific application.

- *Scalability.* An ATM cell can be carried over a 45-Mbps link to a switch and changed into a 2.4-Gbps SONET link. ATM is blind to things like rates or framing.

ATM DISADVANTAGES

ATM has not been aggressively deployed as of this writing, partly because of its inherent disadvantages inherent disadvantages:

- ATM lacks mature congestion control. This is the ability of the network to manage large volumes of traffic in a manner that avoids network information congestion. Congestion control procedures are being implemented, but ATM has yet to be deployed in a heavy-traffic environment.
- ATM can suffer from variable cell delays caused by random queuing delays at each switch. ATM cells are stored in queues in the ATM switch awaiting cell assignment.

There are other issues involving ATM that are not so much problems as concerns that should be addressed from a non-design perspective, with business- or implementation-related. These issues include:

- ATM stands for Asynchronous Transfer Mode and asynchronous refers to the protocol's nonperiodic behavior. Voice transmissions in the public telecommunications network are synchronized with the carrier's switching system.
- The use of ATM switching in the existing network infrastructure requires integration via interoperable network interface standards. This synchronization issue has also been addressed within the framework of ATM.
- ATM has the ability to transmit information and interconnect networks on a point-to-point basis. In ATM's early implementations, the size of the bandwidth or transmission speed was on the order of 150–200 Mbps. Today ATM is carrying such large volumes of traffic that it does not appear that a limit to the protocol's bandwidth will be seen anytime soon.

- The question many corporations and carriers are facing is: "Are there less powerful or complex solutions to connecting networks?" The answer is: "There are less robust and less financially expensive ways to achieve high-speed transmission." This is a matter of balancing capability and capacity with need.

All decisions to select a particular technology over another technology require a careful and methodical investigation into the cost–benefit ratio of one technology over another. Still the overriding question is: "Why ATM?" One way to answer this question is by understanding the uses of ATM.

ATM Cost–Benefit Discussion

ATM can be used to connect networks of all kinds to one another just as SS7 or MF does. However, ATM's advantages over SS7 and MF are the better transmission rate and service types that can be supported. These service types include:

- Voice
- Streaming video with audio
- Audio of music recording industry quality
- Continuous data/information transmissions
- Graphics—high resolution, three-dimensional renderings, etc.
- Interactive multimedia—combining voice, video, audio, and user interaction

These services are all broadband. ATM is the best signaling protocol available today for broadband transmission.

SS7 and MF systems carry data at transmission rates on the order of 0 bpp–56/64 kbps. These transmission speeds are usually enough for most mass-market applications (residential and small- and medium-size businesses). However, they are not sufficient for the newer video, audio, and multimedia applications envisioned, which require transmission bandwidth at OC-12 rates and greater. ATM can be used to support interconnection between different networks, just as both MF and SS7 perform the same function. The ATM switch can be used as an interoperability network element.

Most service providers do not need to support data rates at the OC-12 level at this time, but if the intention is to get into video and data services provisioning, consideration ought to be given to larger bandwidth on the transmission facility side. ATM will be able to integrate a multitude of envisioned services for transport throughout the network. Figure 6.3 illustrates the concept of interoperability using an ATM backbone network.

ATM AND ITS ROLE IN THE FUTURE OF BROADBAND

Essentially, by using ATM, the service provider is able to use its network resources more efficiently for multiple service applica-

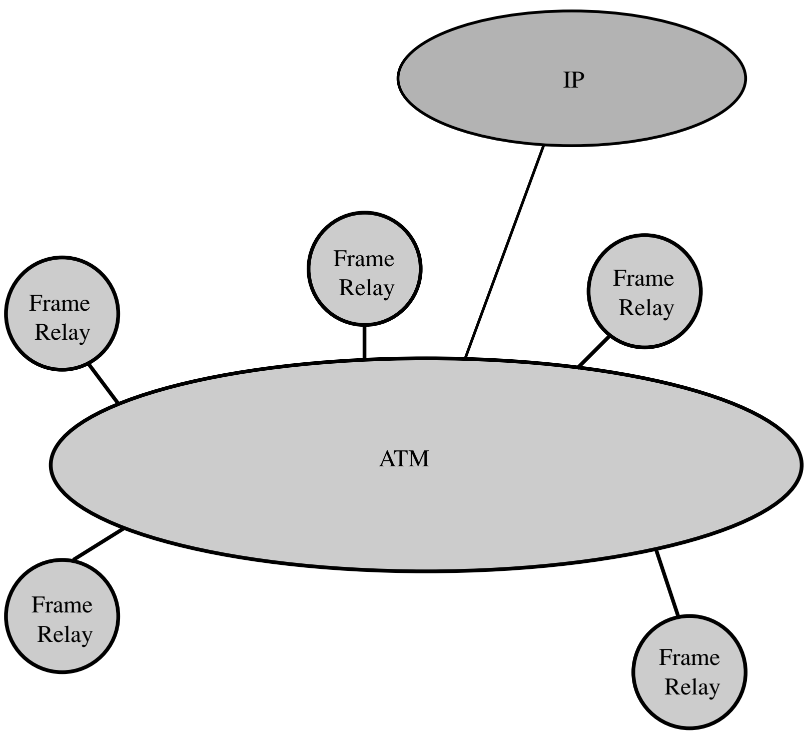

FIGURE 6.3 ATM and Interoperability

tions. In a world in which economies of scale are a critical factor, ATM is very attractive. A few years ago, ATM switching was too costly, but the cost of ATM switches has dropped. The deployment of soft switches has enabled the cost of ATM to drop to a level that is now affordable even to a struggling CLEC.

From a cost perspective, one argument against installing an ATM network is its cost–benefit ratio. Many service providers have only recently completed the installation of their SS7 networks. Interconnection with other networks may mean a speed reduction for service providers that support only ATM switching. In this case the full value of ATM cannot be realized. It is not reasonable to assume existing carriers and CLECs (of any kind) will suddenly change their networks to gamble on projected services that do not yet exist. However, when you consider the entire picture, the argument against installing and operating an ATM network falls short. Large service providers that intend to grow with the industry and move into new areas of the information business should consider the tools needed to be in the business of providing information. The CLECs and incumbent carriers (wireless and wireline) must balance the cost of the system with projected value; it is a gamble on the future but network planning is part science and part art.

The need to install broadband capability is paramount if the telecommunications and information community hopes to see the next generation of telecommunications and information technology. Without broadband capability, the Internet will simply be an e-mail service.

SS7 networks simply are not capable of delivering the broadband video and data services envisioned. A brief explanation of how ATM works is in order. ATM's asynchronous nature is radically different from the current primary signaling methods used by the public telecommunications networks.

ATM MECHANICS

STM stands for Synchronous Transfer Mode. Look at ATM as the complement of STM or "the other side of the coin." STM is used by the traditional voice telecommunications networks (landline carriers) to carry voice and packet data. STM is a circuit-switched networking capability, wherein a connection is established between two end-points before data transfer commences, and torn down when the two end-points are done. Thus, the end-points allocate and reserve the connection bandwidth for the entire duration, even when they may not actually be transmitting the data. Another way of looking at STM is that it is in-band signaling: In an STM network the transmission facility bandwidth is divided into transmission time-slots or buckets.

These buckets are organized into a train containing a fixed number of buckets and are labeled from 1 to N. Each bucket is a car. The train is the entire set of cars. The train itself repeats every time period T, with the buckets in the train always in the same position, with the same facade. In other words, each train car is in exactly the same position as before. There can be up to X different trains labeled from 1 to X, all repeating in the time period T, and all arriving within the time period T. The parameters N, T, and X have been determined by ANSI and ITU standards bodies.

EXAMPLE. You have a set of railroad cars each carrying some type of widget. Each widget is different but is associated with the construction of Big Widget "A". The train may have to make several trips but each trip supports the construction of Big Widget "A".

As the train pulls into the station it drops its load and moves on. If one car is empty it stays empty. As a matter of fact, the train does not stop at this station to get filled. To get filled the train goes to another station.

Now replace widgets with data. Now you have a data connection. Figure 6.4, illustrates the example.

On an STM link, once the connection is established the link stays up for the duration of the call. In an environment of multimedia services, an STM protocol has the difficulty of trying to provide services when each service has different bandwidth and transmission characteristics. Even traffic characteristics are different. If you liken voice, video, and data services to people, you will find that these services are different not only in appearance but also in "personal" characteristics. Each service is obviously

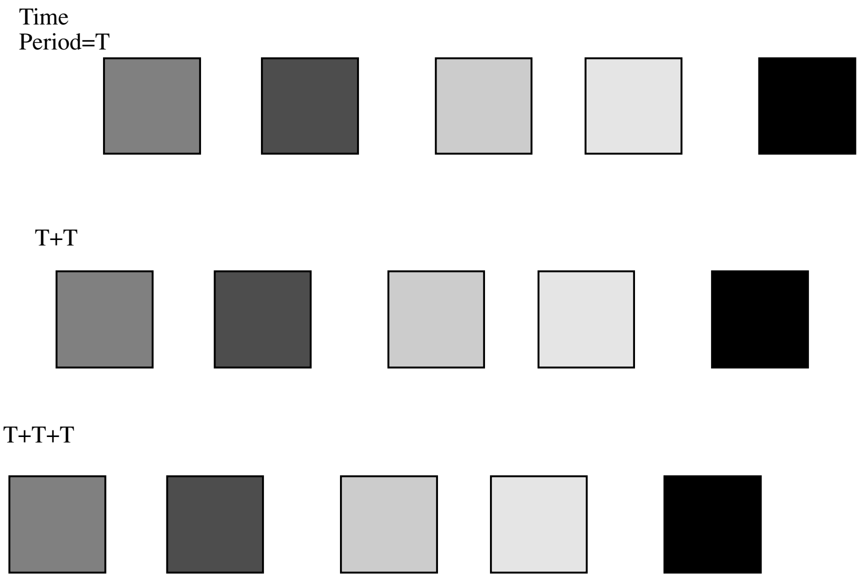

FIGURE 6.4 ATM Mechanics

very different. Each service has a different requirement for transmitting and receiving the information.

The services have their own subscriber groups. Each subscriber group has its own traits and needs. One example is voice telecommunications; voice has the following characteristics:

- It is continuous (i.e., nonbursty transmissions).
- There is real-time conversation.
- There are specific bandwidth needs (normal voice is within the 8 KHz range).
- There is a busy hour for calls. Busy hour refers to a traffic characteristic. It is the time of day when the volume of calls is at its largest. I am not sure about the history behind the term, but I believe the term busy hour was used because this represents the time period for which traffic engineers engineered switch capacity. One hour was used because of the need to engineer around a specific unit of time. There may be more than one busy hour for a switch.

- It tolerates loss but not delay. The loss is information loss, as a result of noise or poor transmission facilities.

Whereas voice has the above characteristics, video has the following characteristics:

- It is in real time. This assumes the subscriber is not seeking slow motion video. If you have ever seen a slow motion video transmission (over an ISDN line) you may find the appearance so disturbing that you will demand high resolution full-motion video.
- It tolerates some loss but not delay.
- It has specific bandwidth needs.
- There is a busy hour for transmission and maybe even reception. This may depend on the industry. For example, broadcast television stations receive some of their programming via satellite transmission one or two days before the public broadcast. If you are in the video conferencing business you will probably have a daylong busy hour; meetings start at the beginning of the day and can go on and on.
- It is continuous.

Data has the following traffic characteristics:

- It is bursty. Data can be sent in large bursts of data. Transmission may be random.
- It tolerates delay but not loss of data.
- It has specific bandwidth needs.
- Real-time is not a requirement.

Combining all three types of traffic or information on a single set of transmission facilities, using STM, would be difficult. If a service provider were to use STM to transmit voice, video, and data over the same network it would be choking its own network. Such a scenario, would be similar to running sets of 20 kilometer-long train cars one after the other without a break. Some of the railroad cars would have information and some would not. Some of the train cars would be different sizes and some would be the same length. The railroad yardmaster would be working hard to make sure each set of trains ended up at its correct destination. STM switching requirements would be pushed passed their limits. STM is designed to handle multigigabit information streams but even STM switches have their limits.

The telecommunications industry trend is multimedia networks that combine voice, full-motion video, and high-speed data on a single network using a single switching platform. This switching platform could be a soft switch, or a combination of voice switches and IP routers to handle the functions of voice, video, and data. Figure 6.5 is an illustration of combining ATM and STM switching to handle voice, video, and data.

Combining the three types of information requires some kind of protocol that allows the service provider to maximize transmission network facilities without losing any data or delay-

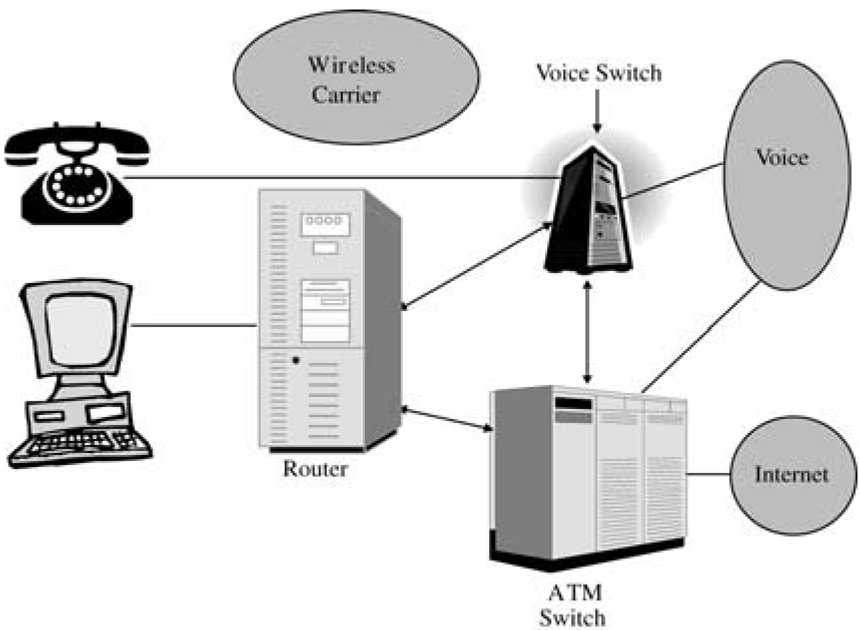

FIGURE 6.5 ATM-STM: A Solution to Handling Multimedia Services

ing the transmission and reception of the data. In order to ensure voice quality, the service provider must have fixed-length information streams. Combine all this and it looks worse than an alphabet soup. In the case of ATM, the soup is made up of information packets. These issues can be resolved using current engineering techniques.

Given the nature of the information mix above, ATM identifies the train cars of information via an identifier called a Virtual Circuit Identifier (VCI). The VCI is carried in the header of each packet of information. At the end of the information stream, the packets are assembled using the VCI as the means of associating each train car.

ATM sounds and looks like a fast-packet protocol. It is designed for switching fixed-length packets. Given the current economics of ATM, it makes sense to use ATM in situations involving the transport of large volumes of data over long distances, like the Internet. The ATM provider can support the TCP/IP protocol used by Internet networks. The ATM network can serve as a national backbone, with the Internet data packet getting broken down into ATM 53-byte cells. The overall network protocol stack would look like this (Figure 6.6):

- Data
- TCP
- IP
- ATM adaptation
- ATM data
- Physical layer

At the time of writing, ATM is fairly new to the commercial market. Manufacturers and service providers are working together to develop applications for an ATM network. At this stage, many of the services are in the visionary category. A service provider can view ATM deployment as a major investment in the future. If the service provider wishes to compete in the broadband services market and be in a position to provide future services, ATM is a step in the right direction.

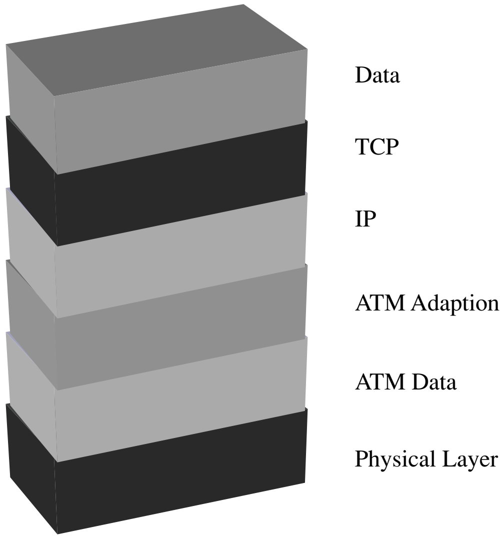

FIGURE 6.6 ATM Protocol Stack

Like SS7, ATM is considered a network investment with no obvious and immediate return on investment. Like SS7, ATM is not only an access technology but also an enabling technology for new services. ATM is the next step beyond SS7, and may be the step towards offering broadband services.

FRAME RELAY

Frame Relay is a packet-switching signaling protocol very similar to X.25. X.25 is a packet protocol that enables connectivity between computing devices and a packet network. The best way to explain Frame Relay is to describe X.25.

X.25 was first deployed in the mid-1960s by companies wishing to interconnect employees with their large mainframe computers at their various corporate offices. X.25 is a packet data, data-link layer protocol; specifically X.25 uses the Link Access Protocol Bearer (LAPB) portion of this layer. X.25 is also supported at the Network layer for packet switching on the D channel and B channel. See Figure 6.7 for an illustration of a Frame Relay network.

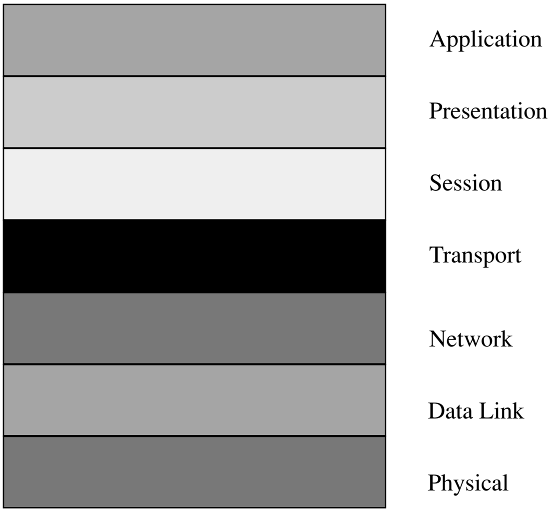

FIGURE 6.7 Frame Relay

In X.25, there is an enormous amount of overhead. This overhead needs to perform the following tasks:

- Each network node must examine every packet that passes through it to determine whether the packet of data can be routed to the next node.
- Every node checks the data packet for errors.
- If a node detects an error, retransmission occurs from the last node that passed that data.
- The process of error checking introduces delays in the transmission and routing of data.

The overhead drives up the cost of the infrastructure equipment, making X.25 an expensive necessity. Frame Relay is a data-link layer protocol that provides the user with the same capabilities as X.25 with a fraction of the overhead messaging.

Frame Relay does not provide any error detection or error correction or real-time flow control between terminals. It is therefore a less cumbersome and less expensive way of providing packet service. Frame Relay is a low-delay and high-speed packet solution. Frame Relay is slower than ATM but much faster than SS7, supporting transmissions of up to DS-3 rates.

Frame Relay takes all the transmitted data and protocol headers and packs them into a frame. This frame of data is sent over a Frame Relay conditioned network. The protocol headers can be from other network signaling protocols, because Frame Relay is essentially protocol agnostic. Despite the fact that Frame Relay itself has little overhead messaging, it leaves the overhead messaging embedded within the transported data undisturbed. Because of this, Frame Relay can serve as an interconnect protocol between different types of networks. More important, Frame Relay can be brought directly to the customer premises using ISDN terminals and circuits. Frame Relay can run over any type of physical medium, metallic or fiber optic.

The frames can be variable in size, up to 4,096 octets. Frame Relay supports packetized voice and compressed video. Given the lower overhead of Frame Relay, building a Frame Relay switching network is an attractive prospect. Virtual networks like Frame Relay networks are alternatives to leased-line networks, which are used by many companies and carriers. Figure 6.8 illustrates the leased-line scenario. In this scenario, multiple transmission facilities are leased from the incumbent LEC. In this network configuration, the carriers use standard facility multiplexers in which the T-1 is multiplexed into 24 channels.

In Figure 6.9, the Frame Relay network enables the carriers to lease fewer transmission facilities. Because the Frame Relay network is a packet network and therefore a virtual circuit network, carriers use standard multiplexing and switching methods to reduce the number of transmission facilities.

ATM in combination with Frame Relay is a formula for a powerful and robust wireline network. This type of network configuration will be capable of supporting high-speed data, video, voice, and multimedia applications. ATM can support the network backbone; Frame Relay can serve as the local access and exit ramps. Figure 6.10 is an illustration of this concept.

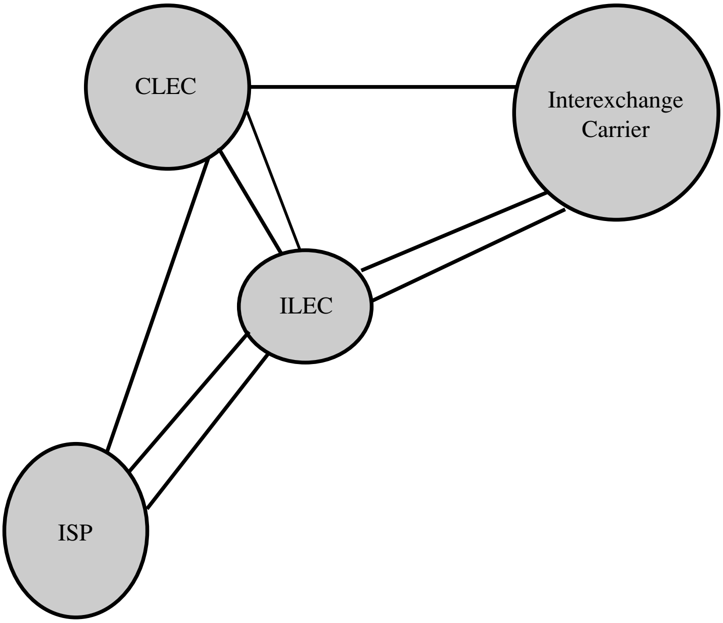

FIGURE 6.8 Frame Relay Networks and Leased Lines

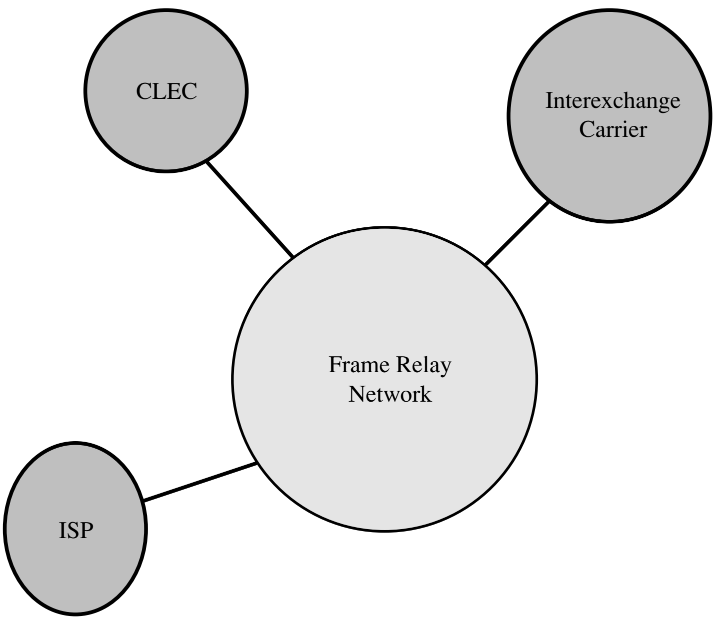

FIGURE 6.9 Frame Relay—Network Efficiency

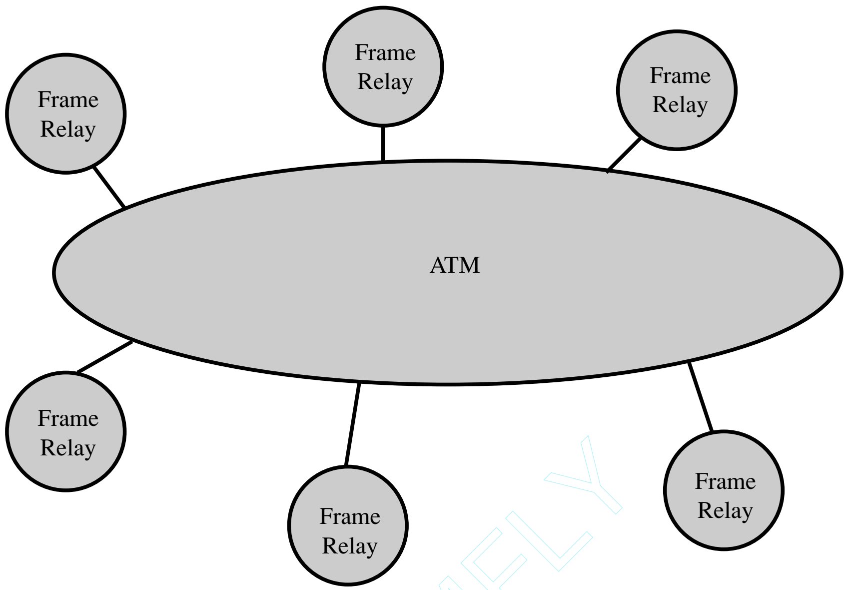

FIGURE 6.10 ATM and Frame Relay

Together, ATM and Frame Relay may be able to bring wireline broadband services into reality sooner than one might expect. (Frame Relay in a wireless environment does not make any sense, given the wireless broadband technologies in place. ATM can be used to interconnect the wireless switches, whereas the 3G technologies can be used to support communications to the base station and handset.)

The next section discusses the specific protocol used to support the current hottest telecommunications market, the Internet. Just as ATM can serve as a backbone signaling protocol, TCP/IP is the network signaling protocol of the Internet.

TRANSMISSION CONTROL PROTOCOL/ INTERNET PROTOCOL (TCP/IP)

The TCP/IP protocol suite was originally, and still is, used for the internetworking of Local Area Networks (LANs). The

Internet is a collection of different networks and providers with different software and hardware technologies. It is, quite literally, a hodgepodge of LANs, servers, small and large Internet service provisioning companies, and search engines. However, the Internet is also a major step toward bringing communications and information to all people. It is a place where information on the most obscure topic can be found by a stroke of a computer keyboard, or one can file income taxes and save postage. Of course, accessing the Internet is not free, but the Internet is the first application of telecommunications that has opened up the world of information and communications in so rapid a fashion. The Internet will be discussed in greater detail later in the book.

All the signaling protocols used in the Internet are part of the TCP/IP protocol suite, which was developed as a result of work first begun by the United States Department of Defense's Advanced Research Project Agency (ARPA) in 1957. ARPA's objective was to develop science and technology in response to the military threat posed (at that time) by the Soviet Union.

The TCP/IP protocol suite is composed of multiple protocols. It is layered, more so than SS7 or even ATM. TCP and IP are just two of the protocols in the suite of Internet protocols. The term TCP/IP refers to this family of protocols. The TCP/IP protocol suite's multiple layers facilitate future development of new Internet protocols. Whether or not this was by design is not relevant for this discussion, but it is fortunate that the suite was built in this manner, for it has enabled software engineers across the globe to find new applications for the Internet.

TCP/IP PROTOCOL ARCHITECTURE

There are four layers to the TCP/IP protocol suite: Physical/Link, Network, Transport, and Application.

The Physical/Link layer (as it corresponds to the OSI model) is also known as the Network Interface layer and manages and routes the exchange of data between the network device and the network. This data or information includes header or overhead information.

The Network layer (as it corresponds to the OSI model) is also known as the Internet layer. This layer is responsible for managing the Internet Protocol (IP). The Internet Protocol provides the Internet addressing for routing. The IP is a connectionless protocol that provides datagram service. A datagram is a method of transmitting information. The datagram is broken up into sections and is transmitted in packets across the network.

The Transport layer in the TCP/IP suite is comprised of two protocols; the TCP and the UDP. TCP stands for Transmission Control Protocol. UDP stands for User Datagram Protocol.

The TCP (Transmission Control Protocol) performs the transport layer functions of the Internet Protocol. The TCP is designed to provide for data connection services to support applications. The TCP contains parameters to ensure reliable and error free delivery of datagrams. The TCP also ensures that the datagrams are delivered without missing packets and in sequence. Let us say that an application sends a file to the TCP. The TCP adds a header to the datagram. The datagram is

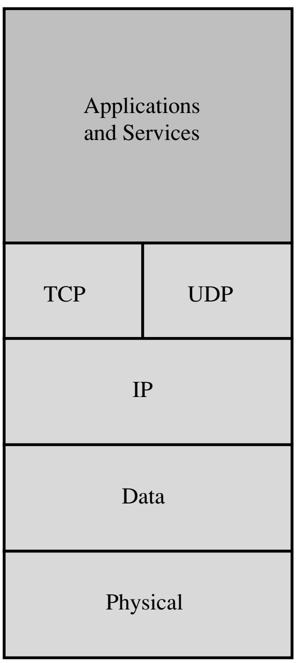

FIGURE 6.11 TCP/IP Protocol Stack

now called a segment. The TCP will receive incoming data from the IP layer then it will determine which application is suppose to receive the segment.

The UDP (User Datagram Protocol) is a connectionless function that is normally used by database lookup applications. The UDP supports stand alone messages like a simple query.

The Application layer is responsible for managing all services. This layer corresponds to the Session, Presentation, and Application layers of the OSI model. The way in which the TCP/IP protocol suite is designed, it will be capable of supporting a variety of different protocols. Figure 6.11 illustrates the layering concept. Figure 6.12 is an illustration of the kinds of protocols that can be supported, which include:

- *TELNET.* A program that enables a user to log on to a computer remotely.
- *FTP.* File Transfer Protocol. FTP supports the transfer of files between computers that are remote from each other.
- *SMTP.* Simple Message Transfer Protocol, SMTP supports electronic mail transmission and reception.
- *SNMP.* Simple Network Management Protocol supports network management.

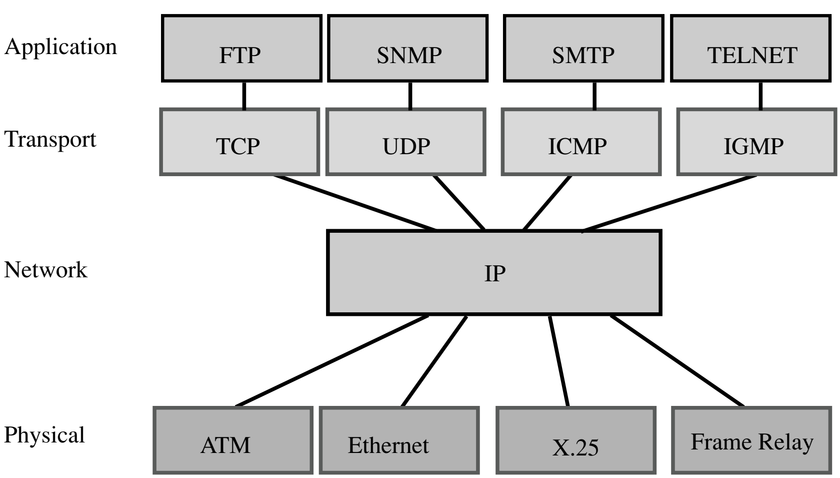

FIGURE 6.12 TCP/IP Protocols Supported

- *TCP*. Transmission Control Protocol.
- *UDP*. The User Datagram Protocol is normally bundled with the IP. UDP supports connectionless transmission.
- *ICMP*. The Internet Control Message Protocol supports diagnostic functions.
- *IGMP*. The Internet Group Management Protocol supports group management on a router.
- *ATM*. Asynchronous Transfer Mode.

SUMMARY

There are a number of network signaling protocols in the marketplace. These optimally perform in certain network and business environments. The challenge for both technology and business is to find the right signaling protocol to support and position the network for broadband services.

As I noted at the beginning of this chapter, network signaling is the exchange of information in a telecommunications network (public and private) that establishes and controls the connection of a call or a communication between subscribers or computing systems and also the transfer of subscriber, end-to-end, and management (subscriber and network) information.

This chapter addressed the wireline or fixed network signaling protocols used to support network element communication and network connectivity. Radio technologies like EDGE, 3G, TDMA, or CDMA are not network signaling protocols that are used to support network connectivity; rather these protocols support communications to their own subscribers.

Without wireline or fixed network signaling protocols there can be no communication between networks and the customers of other networks.

CHAPTER SEVEN

COMMERCIAL APPLICATIONS: BUSINESS SEGMENTS

The telecommunications industry has been working toward bringing a number of user applications to the broadband marketplace; however, none of them has triggered a massive growth in the multimedia segment, even though appropriate delivery services exist. These applications are:

- Voice
- Streaming video
- Interactive Web sites
- Teleconferencing via video
- Entertainment

This chapter is intended to stimulate thought about the kinds of telecommunications providers there are in the marketplace. Chapter 7 will examine the three carrier types:

- Wireline telephone networks
- Wireless carriers
- Internet

After we examine the carrier types, we will consider the kinds of service carriers there could be.

WIRELINE TELEPHONE NETWORKS

To set the stage, let's start with a brief history of telephony in North America. It all began in 1876 when Alexander Graham Bell received a basic patent on his "talking machine." With investment in hand, the American Bell Telephone Company was formed. In 1885 the American Telephone and Telegraph (AT&T) Company was established as a subsidiary of the American Bell Telephone Company to operate the long distance connections among the rapidly growing local Bell telephone companies. These local Bell telephone companies operated throughout most of the nation.

In 1900 AT&T was reorganized into a holding company, becoming the parent of the Bell companies, and making Western Electric the exclusive manufacturing arm of the Bell System. After a series of Federal government investigations and court challenges over a number of years, the Bell System was broken up on January 1, 1984. AT&T provides long distance services and equipment manufacture and sales, and seven regional holding companies, comprising local telephone companies with separate, "unregulated" subsidiaries for competitive activities, providing local telephone service.

During the 17+ years since divestiture, the baby Bell companies have tried to protect their respective markets. Ultimately the baby Bells sought permission to expand into new markets (including long distance) while the long distance service providers sought to leverage their way back into the local exchange market. The result was the Telecommunications Act of 1996. The divestiture of AT&T's local telephone properties and the Telecommunications Act of 1996 have served as opportunities for change in the entire telecommunications industry. The breakup of the wireline telephone companies has been the single most significant event in the last century of the telecommunications industry. Whole new opportunities that have arisen, ranging from voice to video, data, Internet, and satellite. In the industry before divestiture, change only occurred when AT&T allowed the change. There are those who remember the joke that the single most significant event was when subscribers could get a telephone in a color other than black. When the AT&T dike had a hole punched into it, there was a flood of new opportunities. To those without a personal history in the old Bell System, the changes today appear slow and difficult; those with a history in the Bell System, no matter how brief, will see today's changes as rapid.

The industry today is mixture of those with Bell system history and those without it. The skill sets and perspectives in the business today are far ranging, but we should not forget how much of the basic telecommunications traffic engineering, philosophy, and business practices are derived from the wireline telephony business. Remembering and understanding how things were derived will give us an understanding of the interconnected and underlying telecommunications principles and practices.

I have classified Local Exchange Carriers (LECs), Competitive Local Exchange Carriers (CLECs), Interexchange Carriers (IXCs or IC), and Competitive Access Providers (CAPs) as wireline carriers. This is a fairly loose view of the wireline carrier. In reality, a wireless carrier or an Internet Service Provider (ISP) can also be a CLEC or even an IC.

The Telecommunications Act of 1996 has opened the telecommunications market to all comers. Unfortunately, it has not been very successful, for today there are only a handful of super-sized carriers and a slew of small bankrupt carriers.

The landline telephone network is comprised of the following basic elements:

- Class 5 end offices (local switching office)
- Class 4 and 4X switches
- Class 3 switches
- Class 2 switches
- Class 1 switch

The “class” designations had far more meaning and relevance when the old Bell system dominated the wireline telephone network. Generic terms such as local switching office, local end office, and tandem are used today. The current generic terminology is local switch, local tandem, and access tandem.

The following subsections describe the end office and tandem concepts.

END OFFICE

The end office or local switch (popularly known among the predivestiture telecom professionals as the Class 5 switch) provides the subscriber access to the telecommunications network. The end office is the user’s point of interconnect into the larger communications network. It is capable of routing a calling subscriber on a selective basis. End offices typically have more than one route to send out a call. End offices can directly connect each other on high-usage trunk groups when economically appropriate. The end office is a component of the local loop.

TANDEMS

The tandem switch (Class 1, 2, 3, and 4) is a network component used to interconnect end offices when direct trunk groups can not be economically justified and it is also used to connect tandems to each other. The tandem is like a “gateway” to other networks. There are two basic tandems types: local tandem and access.

In a traditional wireline configuration the tandem performs the following functions:

- Connecting end offices to other end offices
- Connecting other tandems
- Connecting other networks
- Accessing interexchange carrier networks

- Accessing operator positions
- Accessing wireless networks
- Connecting centralized functions

The local tandem routes traffic from several end offices to different areas served by other local tandems. The access tandem is used to provide access to other service providers, normally the interexchange carriers. The diagrams, Figures 7.1 through 7.5, illustrate the tandem concept.

WIRELINE TELEPHONE NETWORK/TRAFFIC STRUCTURE

The predivestiture AT&T Bell system network had come to be known as the Public Switched Telephone Network (PSTN). It was organized around two different but interdependent network structures: the local network and the toll network.

LOCAL NETWORK STRUCTURE. The local network consists of customer or subscriber terminal equipment, which used to be a rotary dial telephone set or even hand-cranked units that required manual operator intervention. The subscribers were and still are connected to the local switching equipment by loops of metallic wire. A local switch served a specific set of customers geographically close to it to reduce loop costs and to ensure quality voice transmission. There could be several switches in a building serving the customers in a geographic area. For example, 50,000 customers would be served by two switches, each capable of handling 25,000 customers. The building in which the switches were located was called a wire center. Figure 7.1 illustrates the wire center concept.

The area in which the wire center is located is known as an exchange area. Normally there are multiple wire centers in such an area. In medium and large metropolitan areas (and sometimes in small metro areas) there are multiple switches in a wire center. See Figure 7.1.

Before the AT&T divestiture, a local call was any call between parties within the exchange area, in which there was a single set of charges for calling. Therefore an exchange area

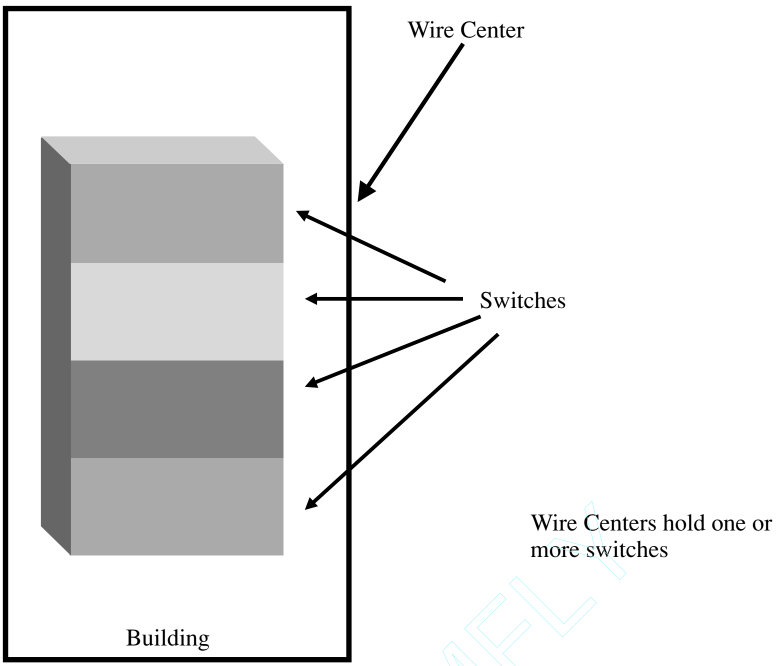

FIGURE 7.1 The Wire Center

referred to a local calling area. Before divestiture, single area codes covered an entire state and one could call anywhere in a state without any long distance charges. After divestiture, a local call was determined based on legal or divestiture court–defined geographic boundaries called Local Access Transport Areas (LATAs). Setting up and completing calls within LATAs is the responsibility of the local exchange carrier.

Setting up calls between LATAs is the responsibility of an Interexchange Carrier. In an inter-LATA call scenario, the LEC sets up the call to an IC tandem, which transports the call across LATA boundaries to another tandem (owned by the same IC) in the called LATA (call this LATA 2). The IC tandem in LATA 2 that receives the terminating portion of the call sends the call to an LEC tandem or local switch. The LEC then carries the call to the subscriber. Figure 7.2 illustrates the relationship between an LEC and an Interexchange Carrier.

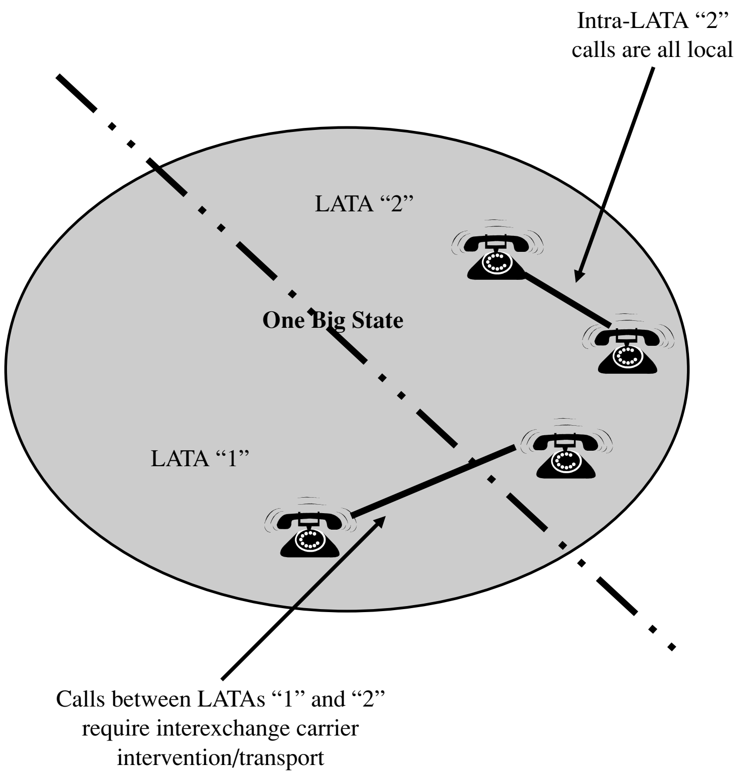

FIGURE 7.2 LATA and InterLATA Calling

Switches are connected to each other via direct high-usage trunks or tandem trunks. The size of the traffic volume determines whether or not switches are connected through direct trunk groups or tandem trunk groups. See Figure 7.3.

Direct trunk groups are employed between wire centers when there is a strong community of interest (in other words high traffic volumes). When the community of interest is low, then a tandem trunk group is used. See Figure 7.4.

Figure 7.4 also highlights the two-level hierarchy used in the local network. Level 2 is comprised of local tandems and Level 1 is comprised of end offices and remote switches.

TOLL NETWORK STRUCTURE. Before divestiture, the long distance network was referred to as the toll network. The term is still used by millions of people in the United States when

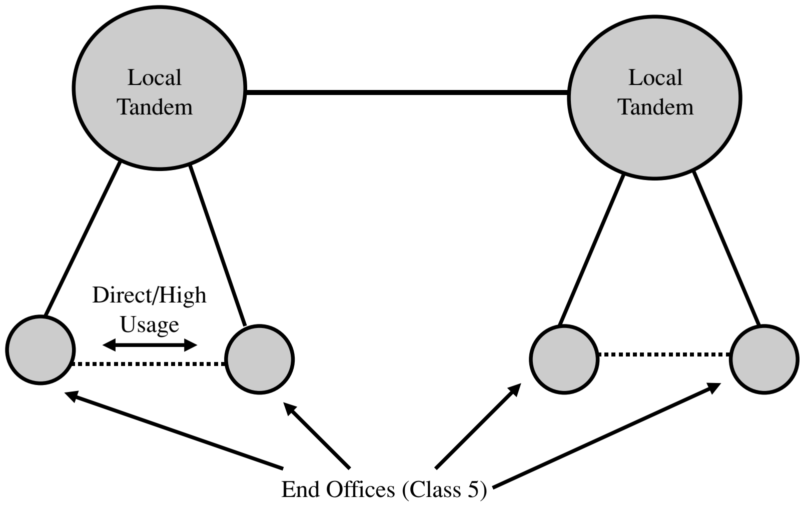

FIGURE 7.3 Direct and High-usage Trunk Groups

referring to long distance calls. The toll network structure defines a methodology for economically connecting and transmitting calls between widely spaced communities. Traffic studies of voice communications have determined that the

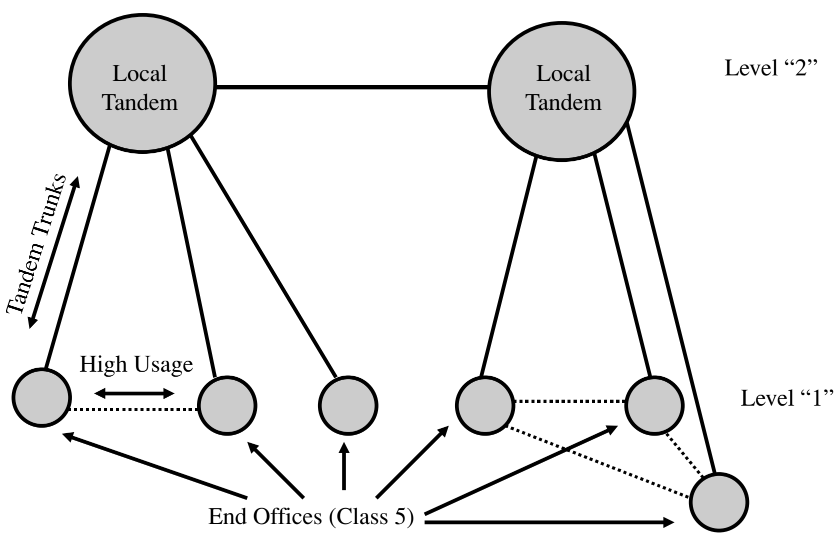

FIGURE 7.4 Tandem Trunking

volume of traffic between two widely spaced communities does not warrant the use of direct trunk groups between the two locations. One example is the number of calls between New York City and Los Angeles. As large as the volume of calls is, it is nowhere large enough to justify spending the money and resources to build a single trunk group between the two cities. The most cost-effective manner in which to transmit calls is through trunk groups that will be shared by multiple communities on each U.S. coast.

The need to connect the entire country cost effectively led to the development of the five-level switching hierarchy used for decades. Figure 7.5 illustrates this hierarchy. In a very high-traffic area usually associated with very dense population areas, local tandems can be interconnected to each other via a local sector tandem. (The five-level hierarchy is described in more detail in my book, *Telecommunications Internetworking*.)

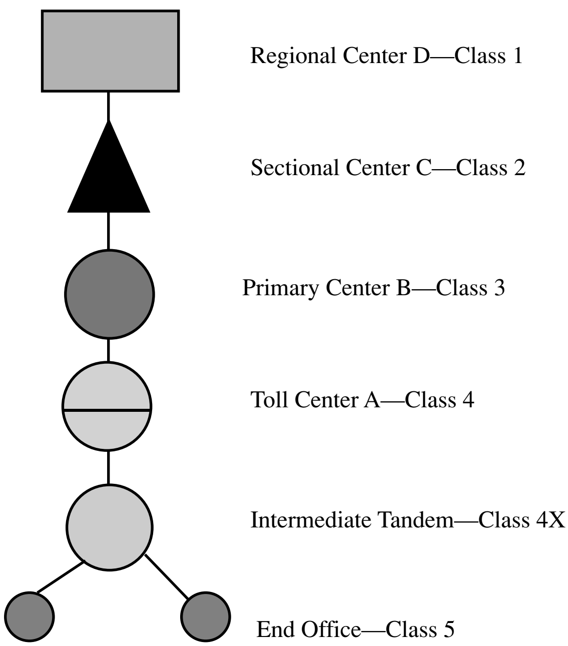

FIGURE 7.5 Five Level Hierarchy

WIRELINE SERVICES—NO BROADBAND

A wireline carrier is capable of supporting the following services. Note that these services are in fact functions that an ILEC performs for itself today:

- Database querying
- Data warehousing (this is new to most landline carriers)
- Call routing
- Service triggers (known to landline carriers as intelligent network triggers)
- Subscriber services
- Billing support
- Network management
- Customer care

Despite the plethora of services provided, none is broadband. The question that arises is: How can the wireline carriers provide broadband services? The answer is, by changing the network and its network elements. Change transmission facilities to support broadband. Install switches capable of doing more than just switching voice. However, making modifications to the network without disrupting the overall traffic structure of the network (it must still support basic voice) will be a challenge. Remember there is a great deal of embedded infrastructure dating back several decades. The challenges can be summed up as follows:

- *Network element modifications.* Wireline switching software may need to be provided to support video, mobility, data, and operational support. This takes time and money to execute. Examples are:
  - Video requires high-speed data processing and transmission facility bandwidth. A wireless environment requires mobility support.
  - Mobility support means the ILEC would need to support:

- Call delivery to a mobile subscriber (home and visiting in a network)
- Roaming (supporting calls to and from visiting subscribers)
- Authentication
- Validation
- Handoff
- Path minimization (efficient routing of a mobile call)

- Creating new billing algorithms
- Modifying traffic engineering practices
- Improving network reliability and availability
- Creating interoperability with legacy systems
- Creating a common billing system
- Introducing a common network management system
- Creating common operational support systems

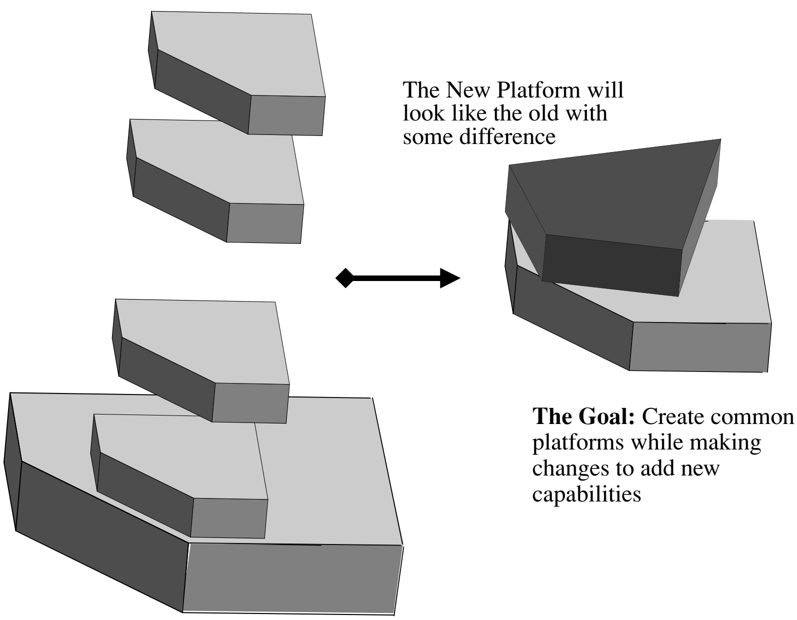

FIGURE 7.6 Upgrading the Traditional Wireline Network

WIRELESS CARRIER NETWORKS

Wireless service includes cellular, Personal Communications Services (PCS), wireless local loop, and satellite. There are other types of wireless carriers like paging carriers and land mobile radio carriers. Here, I focus on the most popular network forms. Each of the carrier types provides service to a different customer segment. We will briefly examine the carriers from the perspective of the customer.

CELLULAR AND PERSONAL COMMUNICATIONS SERVICES (PCS)

PCS carrier systems are radio systems operating at different radio frequency bands. In the United States, these systems, which are operated by cellular and PCS service providers, are the result of two Federal Communications Commission (FCC) decisions made in 1982 (service was first launched in Chicago in 1983) and 1994 respectively. These decisions created the regulatory framework in which these carriers operate.

To the casual observer, the FCC's division of the radio spectrum and national service areas is totally confusing. The following section on regulation describes how cellular and PCS carriers in the United States are allocated, and how these allocations have created brand marketing confusion.

CELLULAR CARRIER—REGULATION

The FCC decision that created the cellular carriers created a structure in which there are two carriers per designated area to which the FCC had issued licenses. The geographic service areas are broken down into two categories: Metropolitan Statistical Area (MSA) and Rural Service Area (RSA).

The FCC awarded one license to the Incumbent Local Exchange Carrier (ILEC) and the second license to a carrier not associated with the incumbent (dominant) local exchange carrier. Note that the ILECs are the dominant wireline carriers in an area; in many areas of the United States, this means the Regional Bell Operating Companies (RBOCs). The ILEC-supported cellular carrier is known as the "B"-side carrier. The nonwireline and non-ILEC cellular carrier became known as the "A"-side carrier. Prior to recent mergers and acquisitions, the distinction of "B"-side versus "A"-side had some clear meaning; however, today the artificial boundaries created by the FCC are blurred.

As an example, Southwestern Bell Corporation originally operated in the southwest of the United States, as both wireless and wireline carrier. Today, Southwestern Bell and BellSouth Wireless have joined forces and are operating in the southwest, northeast, and southeast as cellular and PCS carrier. Southwestern is also operating as both the PCS and wireline carrier on the Pacific coast. BellSouth is still operating as an independent wireline carrier. (As a side note, these changes are part of the convergence we have discussed up to this point.) Figure 7.7 illustrates the "A"-side and "B"-side carrier arrangement.

MSAs and RSAs can cover huge areas of a single state. RSAs are physically larger and cover less dense (in terms of

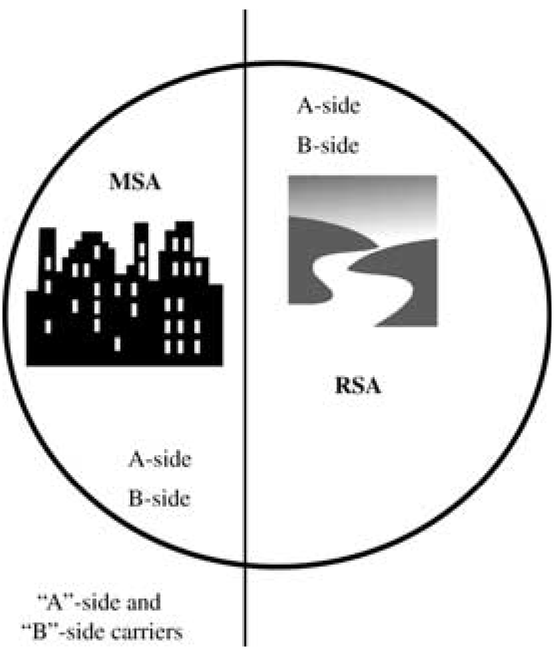

FIGURE 7.7 "A"-side and "B"-side Carriers

population) areas than the MSAs. MSAs and RSAs do not match the federal, state, and local governmental maps that we all know and understand. In other words, an RSA could cover three counties and half another county, or even half one town but an entire adjoining town. MSAs and RSAs are based on statistical population information gathered by the United States Census Bureau. There are over 300 MSAs and over 200 RSAs in the U.S. Note that the MSAs and RSAs also do not match the LATA boundaries established by the FCC for the ILECs as these boundaries relate to Interexchange Carrier relationships. This environment has proven confusing to those working in the telecommunications community and to some extent to subscribers as well.

Figure 7.8 illustrates the relationship of MSA and RSA to the LATA. A logical relationship does not exist.

The area in which the cellular carrier is actually providing service is called the Cellular Geographic Service Area (CGSA). This service area can cover multiple towns and communities; MSAs and RSAs even overlap states.

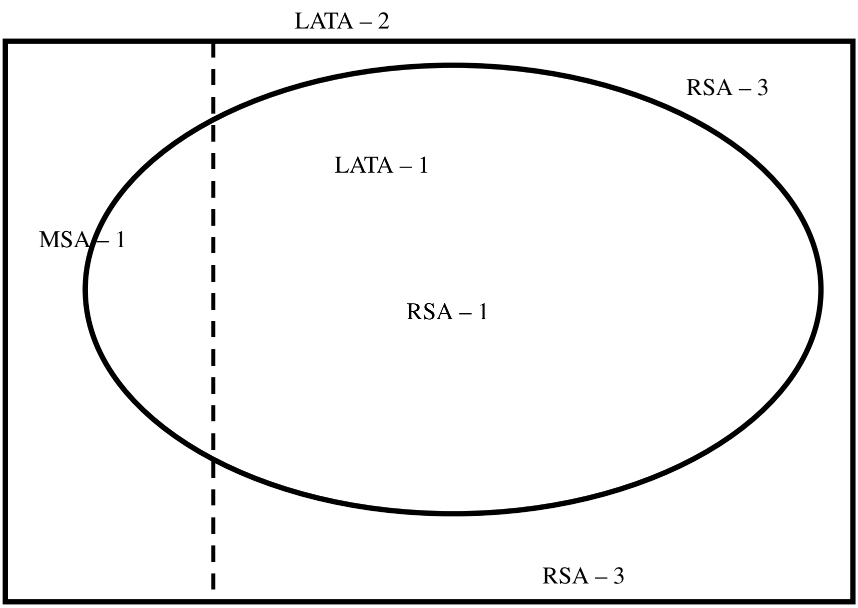

FIGURE 7.8 MSA, RSA, and LATA

PERSONAL COMMUNICATIONS SERVICE (PCS) REGULATION

In the United States PCS is supposed to be the next generation of cellular, operating in the 1900-MHz band. However, what is apparent is that PCS is cellular engineering applied to a frequency band different from that used by the cellular carriers. In the beginning, PCS was supposed to be everything that cellular was not and could not be. The reality is that technology advancements make cellular as competitive as PCS. One of the advantages over cellular that PCS was supposed to possess was the use of legacy equipment; i.e., PCS operators did not have to worry about maintaining the "old" analog radio systems that the cellular carriers had to worry about. This translates into the fact that the cellular carriers had capital out in the field; PCS carriers did not have to expend money to maintain and upgrade systems to be competitive.

FROM THE PERSPECTIVE OF THE CELLULAR CARRIERS

The cellular carriers have an existing customer base, but the problem with being the "big dog" on the block or "King of the Mountain" is that there are others nipping at your shoes or taking shots at your back.

- Cellular carriers have the burden of existing infrastructure to deal with, while PCS carriers are deploying new infrastructure.
- Cellular carriers have a need to upgrade existing equipment to compete with new carriers coming into the marketplace.
- PCS carriers have the burden of generating enormous expenditures in order to create a profit-making network.
- PCS carriers are dealing with a two-edged sword. Cellular carriers can make the same case: upgrading aging equipment while deploying new infrastructure to meet the needs of an expanding marketplace and new coverage areas. In the case of the cellular carrier, the two-edged sword is not as big or nasty.

The major differences between cellular and PCS have more to do with business and regulation and less to do with technology.

PCS licenses were awarded to six carriers per service area. The service areas were broken down into two categories: Major Trading Area (MTA) and Basic Trading Area (BTA). Rand-McNally has defined 51 MTAs and 487 BTAs in the United States of America.

Note that MTAs and BTAs do not match the contours of MSAs and RSAs. Furthermore, they do not match the contours of LATAs. Figure 7.9 illustrates the relationship between MTAs, BTAs, MSAs, and RSAs.

Figure 7.10 illustrates everything we have seen in Figure 7.9 and overlays the LATA structure.

CELLULAR AND PCS NETWORK CONCEPTS

Cellular and PCS have the same basic objectives because the goals of all service providers are the same: provide service at a profit. The goals include:

- *Efficient use of the spectrum.* Useable radio spectrum is not as plentiful as one might imagine. In order to create the new PCS carriers, some of the 1900-MHz bandwidth had to be cleared of state and local users. Many underestimated the number of users operating at those frequencies. During the

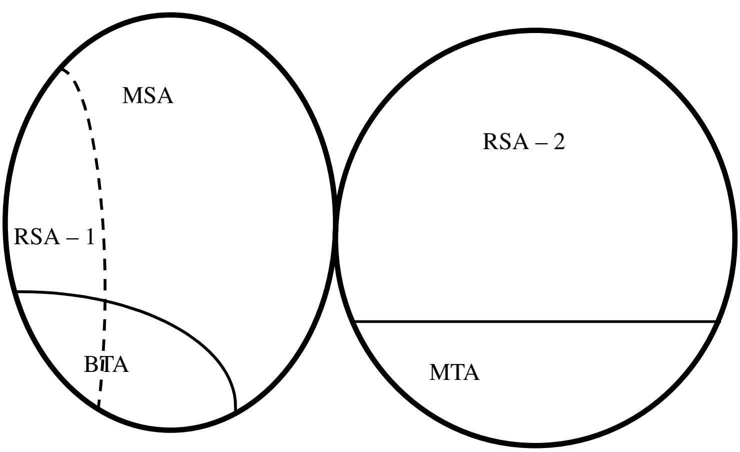

FIGURE 7.9 MTAs, BTAs, MSAs, and RSAs

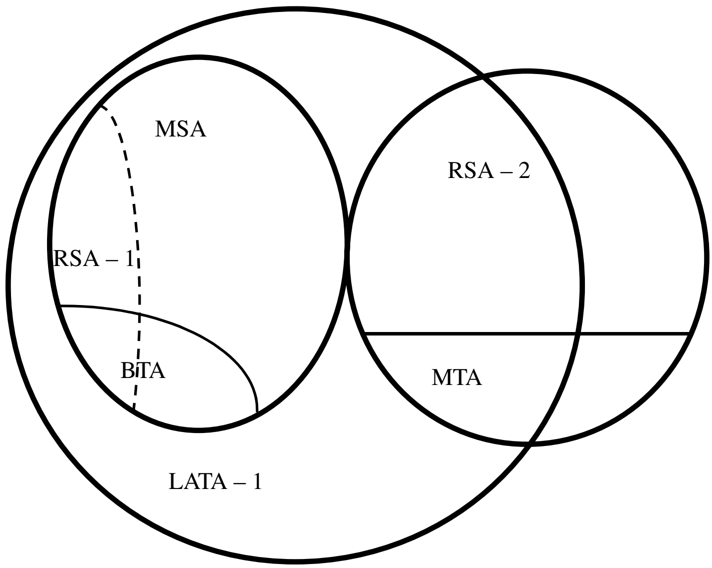

FIGURE 7.10 Overlaying the LATA over the Cellular and PCS Coverage Areas

original comment period of the FCC PCS notice of proposed rulemaking, hundreds of companies and local government agencies cried out in protest. The FCC established provisions for these users to be moved and financially compensated.

- *Customer capacity.* The system must be capable of handling all of the projected users, including anticipated visitors.
- *Smooth and transparent system growth.* Growth in the system should occur in a manner that does not affect the subscriber and is transparent to the subscriber's services. This transparency concerns the effect of adding new systems or enhancing new systems in a way that does not have an adverse impact on the subscribers.
- *Tailored radio coverage.* The cellular and PCS system should be designed to fit the RF (radio frequency) topological environment of the coverage area. This tailoring will enable the carrier to design and engineer a cost-effective system that meets the carrier's needs. Just installing towers and radio equipment will likely produce a network that is incapable of meeting the needs of the subscribers.

- *Nationwide accessibility.* A subscriber of one wireless carrier should be able to obtain service within the operating territories of other service providers. This should occur without manual operator intervention. While some PCS systems will not enable a user to roam onto a cellular system, some carriers are using tri-mode handsets that enable subscribers to roam from one carrier to another and between frequency bands (i.e., 800 MHz and 1900 MHz).
- *Affordability.* Cellular and PCS service should be affordable to the subscriber. This is a simple concept. Carriers want people to buy their service, therefore it should be cheap enough to entice people to buy wireless service.
- *Acceptable Quality of Service (QoS).* During the original AT&T Bell Labs study there was a feeling that the quality of wireless service ought to be similar to the quality of service a user expects from wireline service. However, as many wireless users have found, wireless carriers do not have a "standard" for quality of service. In fact many subscribers believe that the QoS for wireless is substantially lower than that for wireline.

CELLULAR AND PCS BROADBAND SERVICES

As I have already noted, cellular and PCS carriers are attempting to provide broadband services via interim and established 3G technologies. 3G is defined as wireless broadband. The 3G technologies include:

- EDGE
- High-Speed Circuit Switched Data (HSCD)
- GPRS
- CDMA2000
- Wideband CDMA

There are a plethora of definitions for 3G because of the commercial drivers behind the marketing hype. The United States FCC has defined 3G as:

- Supporting circuit and packet data at
  - Data rates of 144 kbps or higher in a mobile environment
  - 384 kbps for pedestrian traffic
  - 2 Mbps or higher for indoor traffic
- Providing interoperability between vendor systems and, possibly, carriers
- Supporting roaming through
  - Standardized call detail record formats
  - Standardized user profile formats
- Capable of determining the geographic location of mobile devices
- Supporting multimedia services and capabilities through
  - Fixed and variable rate bit traffic
  - Bandwidth on demand
  - Asymmetric data rates in the forward and reverse radio links
  - Multimedia mail store and forward
  - Broadband access up to 2 Mbps

SATELLITE

As I noted earlier, satellite is particularly well suited for graphics-heavy data. It is also more cost effective than T-1 for running business applications involving weekly or daily downloads of large files.

The following is a list of standardized satellite services and capabilities currently being provided by this segment of the telecommunications industry, in standardized industry terms. There are also a number of space radio communications services.

- Fixed, mobile, broadcasting and earth exploration satellite service
- Space research service
- Space operation service

- Radio determination satellite service
- Amateur satellite service
- Intersatellite service

SATELLITE WIRELESS BROADBAND

Satellite wireless broadband has been provided for years. The industry is moving toward using the Ka-band because it is available and because small consumer antennas can be used. Satellite systems have supported the following kinds of broadband services since satellite communications' commercial inception:

- *Entertainment.* Includes television programming and radio programming
- *Education.* Includes distance learning and research
- *Data transmission.* Includes data transmission to support businesses, financial transactions, and video
- *Public telecommunications.* Includes wireline, cellular, PCS, paging, Internet access, and other types of wireless telecommunications

The satellite carrier providing handset-based services has not been very successful. Poor business plan aside, the stock market downturn did not help already financially strapped satellite companies. However, I believe that soon a satellite company will find a way of successfully running a mobile handset-based communications business. This may sound a bit far fetched, but a cellular or PCS carrier could extend its service reach into countries with minimal wireless or wireline infrastructure by using satellites.

WIRELESS LOCAL LOOP

Wireless carriers have the technology to penetrate the local loop. Even with the various broadband transmission hardware technologies in the marketplace, only the ILCE has unrestricted access to and control of the local loop.

However, even the line-of-sight (LOS) wireless local loop companies need to wire their customers' premises for that "last mile" within the building. Nevertheless, the amount of hard wiring the LOS carrier needs to do is small and only within the building, not in the neighborhood.

The LOS companies of today are probably the best suited, to break into the local loop and bring customers the slew of broadband services envisioned. LOS carriers have access technology and large amounts of spectrum. They can also use cellular carrier and PCS carrier frequency-reuse techniques to increase and manage capacity of the system. My book *Telecommunications Internetworking* describes the cellular and PCS cell site engineering concepts.

THE INTERNET: A BROADBAND BUSINESS SPACE

The Internet business space is the market every telecommunications business and "wannabe" wants to enter, and has been the focus of broadband engineering efforts. Telecommunications engineers and business people have been trying to find the killer Internet application. I do not believe there is such an application, but I do feel that the Internet opportunities have to be layered in order to build the appropriate business case. Broadband is *the* issue that the business and technology communities need to focus on. If they can find a way of cost effectively bringing bandwidth to the home and businessplace over the wired network, they will trigger a chain reaction throughout all the other business segments and drive broadband services. The first area in which broadband services will take off is in the Internet business space.

The Internet was conceived in the 1960s. The concept was captured in a report written by the Rand Corporation for the United States government. This report outlined a vision of a future information network, describing a view of information as a material good and the principal commodity of the twenty-first century. The United States government's Defense

Advanced Research Project Agency (DARPA) invested several billion dollars in developing packet-switching networks from the mid-1960s through the early 1970s. Initially, the customer for these switching networks was the Department of Defense. However, many of the researchers who had contracted to carry out the research and development were academics. They became enamored of the test systems they built and realized their work had applications beyond defense. Initially the research network was called the Advanced Research Project Agency Network (ARPANET), and later the Internet (Inter Network). The first e-mail was sent in 1972. Figure 7.11 is an illustration of the Internet.

WHAT IS THE INTERNET?

By the very early 1980s, two other important pieces of technology had emerged in the United States. The first was the workstation/server system, which was becoming the way to provide

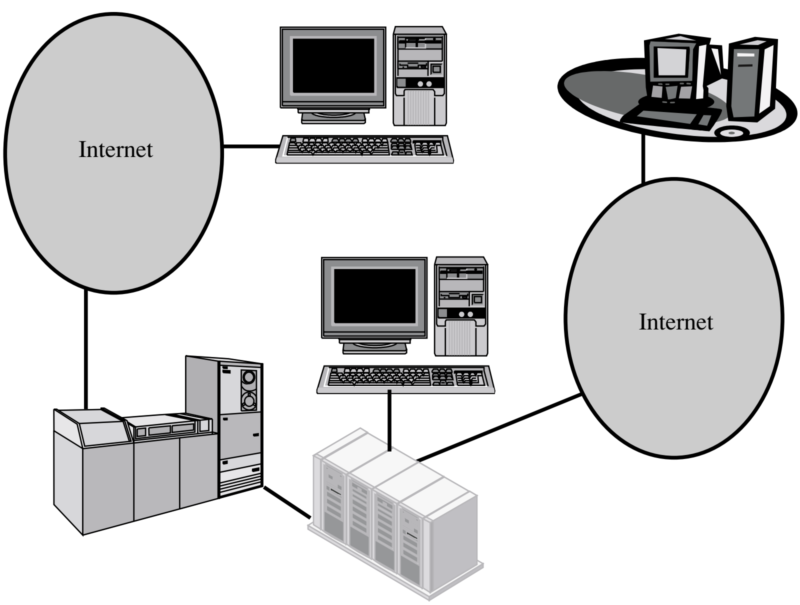

FIGURE 7.11 The Internet

cost-effective computing to the desktop. The second was the Ethernet Local Area Network (LAN). The Ethernet was widely accepted as the way of providing communications between the desktop and server computers in the same organization (LAN). The computer and information technology researchers involved used all these systems for computing and for local and national communications. The United States government had funded most of the initial implementations of the Internet technology on the basis that it would be made freely available to others.

By the mid-1980s, a large number of universities and research labs in Europe and the United States had access to the Internet through government-subsidized network links leased from the public network operators. However this changed rapidly, so that now many Internet connections are paid for directly by the subscribing organization.

INTERNET NETWORK ARCHITECTURE

The Internet is an excellent example of convergence. It is an open pipe of information that allows access from anyone who uses a computer or some type of access terminal device. The Internet currently carries voice, data, and video (real-time and stored).

The Internet is not a single network but rather a web of networks (a network of networks). Intelligence does not reside in a single component of the Internet but is embedded within the components of individual network elements. When you compare the Internet with the older and traditional voice networks you will find that the Internet is decentralized in its intelligence and control. The power of the Internet is in the software supporting the applications and within the protocol itself. No one controls the pipe. Figure 7.12 illustrates the distributed intelligence of the Internet.

Another way of looking at the Internet is that the public telecommunications networks (PSTN and wireless voice networks) view voice as their principal business and data (nonvoice information) as a line of business to be entered heavily. The Internet, on the other hand, looks at data (nonvoice information)

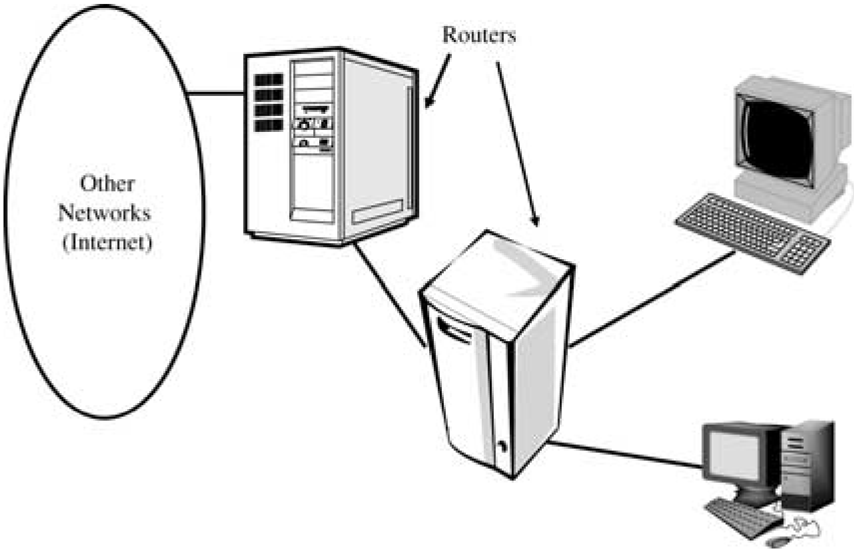

FIGURE 7.12 Internet: Distributed Intelligence

as its principal line of business and voice as a line of business it is beginning to enter heavily. The traditional public telecommunications carriers, satellite, and cable television are all seeking ways of entering the Internet business. The challenge for these companies is understanding what service they will be providing.

Internet is not a product but an information medium that supports bidirectional transmission. It will be the catalyst to produce the next-generation telephone company and information carrier. If it is credible that the Internet will be as pervasive as many have stated, then it will become as commonplace as the telephone in the home and business.

(More information about the Internet can be found in my books, *Telecommunications Internetworking* and *M-Commerce Crash Course*.)

NEW TYPES OF TELECOMMUNICATIONS SERVICE PROVIDERS

The reality is that with the advent of the Internet, telecommunications carriers have been facing the possibility of small companies, and even individuals, threatening their business. Various multimedia application programs and content have enabled the small company and individual to create new media opportunities. These opportunities all center on the Internet in some manner. New opportunities created by the birth of the Internet include:

- *Online music.* Initially Internet music companies were giving music and new songs away. Now the artists who created the music and songs can get paid for their work. Recent copyright infringement suits have resulted in these Web music sites being forced to cough up the money owed to those people who sweated over creating the music and songs.
- *E-Commerce sites.* Doing retail and wholesale sales over the web.
- *M-Commerce sites.* Doing retail and wholesale business over the wireless Internet.
- *Electronic publishing.* Online books.
- *Corporate directory services.*
- *Internet-based video conferencing.*

Figure 7.13 illustrates these services and how they apply to the user.

None of the opportunities listed is what one might call a "show stopper." The fact is, none of these services has changed the fundamental way people do business. "Doing business" has always been and always will be about relationships first and usefulness second. None of the video and audio services over the Internet has caused the telecommunications industry to exhaust its resources to bring services to the marketplace quickly.

The challenge for any provider of service has been to offer a service that has an obvious utility for the customer. The Internet has created additional avenues for the businessperson to conduct transactions but the fundamental way business is done has not changed. You still need to have product brochures, still need to see the customer (maybe not as frequently but "face" time

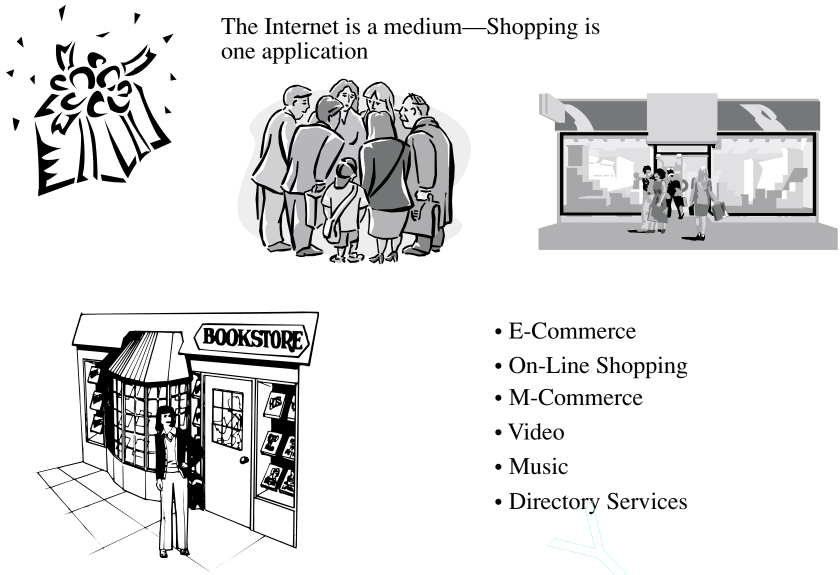

FIGURE 7.13 Internet-based Services

will never be totally replaced), and still need to sign legal papers to close the transaction.

Two very useful services recently discussed in the news have been related to the movie industry. Both services require broadband technology and the Internet. Movie production companies (studios) have been seeking to improve the distribution of films and to reduce the cost of distributing films to thousands of movie theaters. One way of accomplishing this is via the simulcast of the film from the movie studio or other single source to all theaters. This would reduce the costs of distributing a film and reduce the cost of making thousands of prints of a film. A further benefit is that the theater owner would not have to spend money on archiving the software copy of the film for showing.

Another benefit would be the ability to show the film using high-resolution video. However, the cost to theater owners of distributing and showing films in this manner is prohibitive. Another way of using the Internet and its broadband capabilities is to send the theater owners their own individual copies of the film. The film could then be shown by the theater owners on their own schedules. This would reduce the cost of distribution. However, the cost of equipping theater owners with the necessary technology is still prohibitive. Figure 7.14 is a representation of how a movie could be distributed.

This movie-industry application has an obvious benefit to the user—a service that requires the provider to spend an inordinate amount of time explaining why a service is useful means that the service is not useful and probably will not generate revenue.

THE KEY TO CREATING SERVICES

A number of different industries can use broadband technology to support business, without the Internet. Although the Internet medium has the highest potential for using broadband technology, it is important to remember is that a service must be useful and not merely something that looks "neat," "cool," or "awesome" because it is different. Early adopters of technology gravitate toward trying things out because the product or service looks different. However, early adopters do not generate enough revenue to support a company.

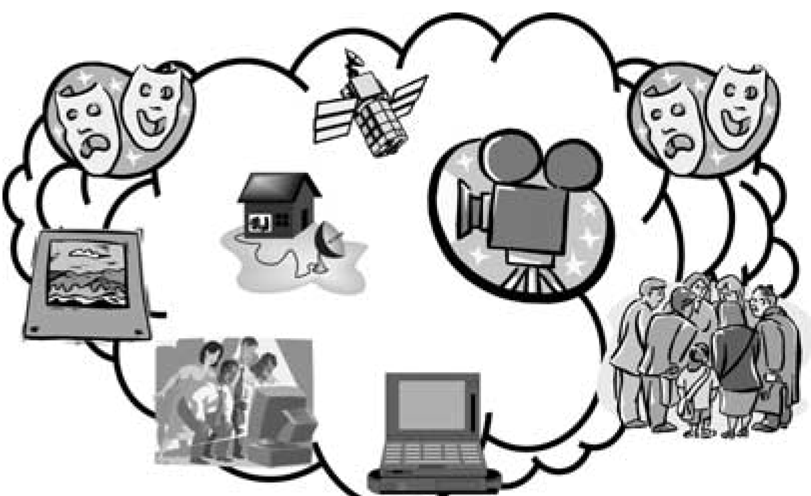

FIGURE 7.14 Potential Internet and Broadband Service—Movie Industry

The key point to bear in mind is that the service or product must have everyday usefulness. Figure 7.15 is a graphical representation of the need to focus on usefulness.

SUMMARY

The marketplace is driving broadband service development down a path guided by business and market parameters familiar to all of us. The challenge for broadband services players is to find that niche or mass-market idea that will create and increase the broadband services business. A guiding principle for broadband services player is first to look at how things are done today and then look at how an idea can add value, which is a very basic way of approaching any matter.

The marketplace is always seeking new ways to improve the quality of life by making things:

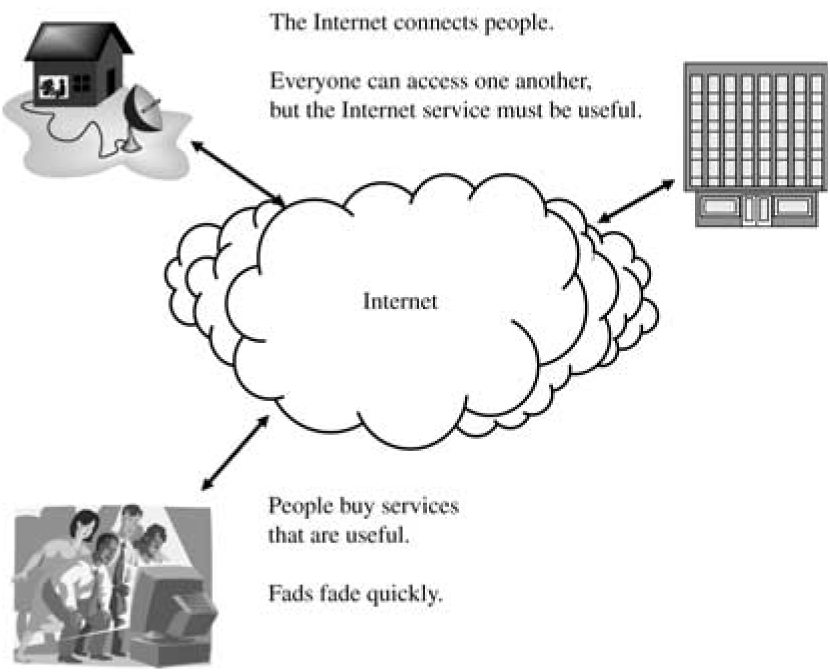

FIGURE 7.15 Usefulness to the Customer

- Easier, faster, less expensive, and/or more fun
- Easier to find
- More interesting to perform
- More interesting and higher in quality to view or listen to
- Useful in everyday activities

The telecom business space is not just about providing services to the user but about providing services that the user will pay money for. The typical cycle of service creation involves the telecommunications engineer developing a brand new technology and service application without the benefit of a marketing person. Unfortunately, as in any business, the telecommunications product marketing person is the last person to become involved in the service creation process. The pace of technological change in telecommunications has reached a level where it has become exceedingly difficult for the marketer and the engineer to synchronize their activities. Marketing requires one to observe the marketplace behavior and forecast the needs of the marketplace. Technology development can and often occurs in the absence of consumer input. The carrier community must ensure that communications between marketing and engineering exists or the chances of market failure will be great. The key point for a carrier to remember is that customer must be the focus of all company activities.

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C H A P T E R
E I G H T

BROADBAND CONVERGENCE

Convergence is about as good a word as any to describe what is occurring in the telecommunications industry. Corporations are finding synergies in their business plans and, by using these synergies, are either building new business or enhancing existing businesses. Broadband technology has been a catalyst behind this convergence.

Telecommunications technology sectors have been converging efforts to create more bandwidth, opening the pipes wider. These efforts have attacked the issue from multiple angles, wireless industry has been working to implement its 3G technologies. The wireless local loop LOS carriers have been working to bring more bandwidth directly to the customers and bypass the ILECs and the wireline industry has been working toward opening its transmission facilities via fiber optics and new signaling protocols. Figure 8.1 is an illustration of the industry's efforts.

The most prevalent form of broadband technology today is satellite and cable television transmissions. Until recently, television had been broadcast from some central location, terrestrial and space based. Today, however, television is broadcast over coaxial cable to the home from the cable television companies.

During the mid-1990s, the entire world was engaged in a development war over high-definition television (HDTV). Just

FIGURE 8.1 Broadband Industry Efforts

imagine if several national governments, multinational corporations, and the financial community were all engaged over a global debate and business war over Television, which supports the largest information segment in the world: entertainment. Entertainment includes news, movies, television programming, and sports. Television crosses multiple entertainment segments and each segment generates tens of billions of dollars in revenue. The combined global revenue is in the hundreds of billions of dollars.

The challenge for the broadband industry is finding a need to install the technology. To some extent, we are facing a chicken-and-egg problem. On the one hand, more bandwidth means more information can be transmitted to the customers. On the other hand, the technology costs money and someone has to pay it. Unless there is a customer demand that cannot be met with existing alternative technologies, the broadband technology will not be deployed. More important, after the users' needs have been discerned and addressed, a company still needs to write the business case that will decide whether or not the technology will be deployed.

BROADBAND ATTRIBUTES

In Chapter 1, I defined broadband by first defining what it was not. I noted that broadband is the opposite of baseband. Baseband transmission is the transmission of a single signal over a transmission medium. Broadband is the transmission of more than one signal over a transmission medium. This is only half the technical definition and still does not really tell you at a "gut level" what broadband means.

Broadband services are comprised of voice, video, audio–music, graphics and data.

There are multiple forms of media combined to enable a user to interact with the information in a hands-on manner. Broadband services do not simply bring the user a world of information from a multitude of sources. They enable the user to interact with the medium in a way the user can control.

This is what the telecommunications industry is envisioning broadband to be. The real question is: Who will use the broadband services?

WIRELESS BROADBAND: 4G

What comes after 3G? Wireless as a commercial vehicle evolves because it must; otherwise, it will be replaced by some other type of product. The 4th generation of wireless will likely include:

- Video
- Higher-speed data
- Internet Protocol (IP) compatibility, which will result in full compatibility with the World Wide Web (WWW)
- Seamless roaming among different telecommunications systems, wireline and wireless

These assertions are an educated guess based on the current work efforts in the technology community. By the time these efforts are ready for commercialization, the industry will already have deployed 3G systems. From a sales and marketing and technical perspective, it is better to take small- to medium-sized steps when deploying new products and services. Early visions of 3G included:

- *High-speed data*
- *Mobile Web access.* This did not necessarily mean WWW access
- *Seamless roaming.* The seamless roaming referred to is roaming between geographic markets and possibly between wireless carrier types. This did not include roaming between different telecommunications systems types.

Wireless broadband has been a hotly discussed topic within the technical community for the last several years. Only recently have the discussions moved from the technical to the business realm. The typical path of the birth and life of a telecommunications service starts as a technology discussion that may turn into a standards effort. Product marketing strategists don't enter the picture until this technical effort is nearly complete, but to be effective marketing and sales people should be connected to the process of technology creation, to provide user-group insights. The industry needs to be able to monitor and predict the marketplace's needs. The challenge for any marketing organization is to predict what the market will want based on its past and current actions.

THE LOCAL LOOP BANDWIDTH BARRIER

The industry has found a way to penetrate the long distance (aka, long haul) market using fiber optics. The use of fiber optics in connecting networks and cities across the country is as commonplace as the television set is in the home. However, not commonplace is fiber in the local loop. True there is fiber in cities connecting businesses to carriers, however, when compared to the amount of copper facilities in the street the penetration in the local loop is insignificant.

The telecommunications industry has solved the bandwidth limitations in the long haul market but it has not solved the problem in the local loop market. There have been efforts to increase the bandwidth to the home and business. Examples of local loop bandwidth efforts have involved xDSL and even T-1 directly to the home or business. The fact is that these efforts have not been successfully deployed on a wide-scale basis due to cost and technical limitations. From a technical perspective, xDSL is dependent on the condition of the existing local cooper outside plant (the loop). T-1 can only handle up to 1.544 Mbps transmission speeds. If the Internet is to succeed commercially then higher bandwidth rates are needed. This is the challenge: Breaking the local loop bandwidth barrier.

Fiber at this moment appears to offer the greatest opportunity to offer enormous bandwidth to the home and business. The problem is that fiber is not deployed to homes or small to medium sized businesses (most businesses are small- and medium-sized—under 1,000 employees). Wireless can offer an alternative to xDSL or even T-1 to the home and business. However, wireless today cannot offer data rates at speeds in the gig bit per second range.

The industry fiber effort underway is an application of technology known as the Passive Optical Network (PON). The PON is a method of bringing fiber to the home or community in a lower cost. PONs use optical bandwidth splitters. The technology works but it has yet to be deployed cost effectively. Part of the cost issue is the cost of labor and cost of components. The cost of equipment is dropping but the cost of labor has not.

When some industrious business person finds an application or set of applications that a customer will pay money for then the PON will become cost effective. In other words, once the business case can be written and supported the use of fiber will become more attractive.

THE INTERNET

The Internet is the ultimate user of the bandwidth that the fiber and wireless technologies are bringing to the marketplace. The

Internet is evolving. As distressed as the financial markets have become one thing to bear in mind: telecommunications demand is neither going away nor decreasing, it is growing. The Internet is not dead, it is just at a point of business growth that all telecommunications services, since the beginning of the industry, have gone through. The technology has been deployed before the product marketing and business strategist folks have developed definitive service strategies. The creation of commercial services is an ongoing development cycle between technology and business. You need technology to provide services, however, the engineers don't write the business cases, yet the business folks want to sell services, the same business folks won't sell what does not exist or has not been proven in a trial, an finally it is the business folks who have to fund the service.

The Internet went through a massive period of technological growth. The technical community had an opportunity to create new tools for creating services and new content. However, the marketing folks needed the time to test the consumer market to determine what kinds of services people wanted to buy. Unfortunately, the financial markets did not understand the telecommunications service-creation process, its capital funding implications, or even the marketplace. This resulted in a massive number of companies all claiming market domination. There have to be winners and losers in the marketplace. When you have a thousand companies all claiming the top prize it just is not being realistic.

The Internet has value and will need to do the following:

- Support voice
- Support video
- Be WWW compatible
- Be secure
- Support broadband data of all kinds
- Be accessible by all kinds of terminal devices
- Be ubiquitous throughout the nation
- Support mobile and wireline web access

The value can only see the light of day if there is enough bandwidth to support it.

Figure 8.2 is an illustration depicting the convergence of telecommunications technologies.

Figure 8.3 is an illustration of the telecommunications industry.

WHO WILL USE BROADBAND SERVICES?

The broadband services market suffers from case technology marketing hype. The vision of a technology's capabilities has outpaced the market research and product development work that is needed.

Communications markets can be broken down and combined in any number of ways, however, the broadest categories are:

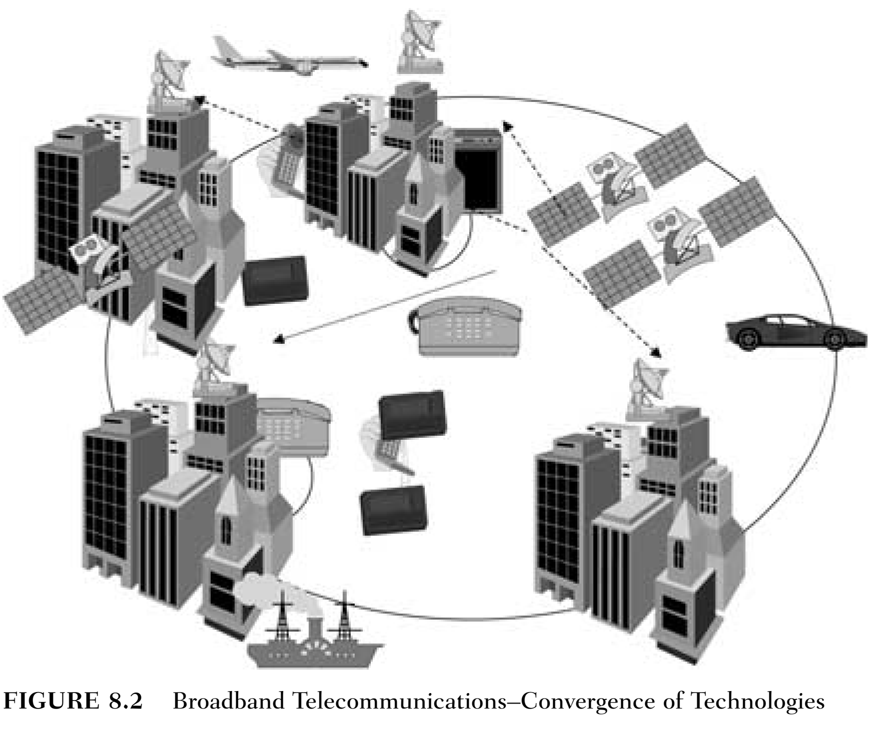

FIGURE 8.2 Broadband Telecommunications–Convergence of Technologies

FIGURE 8.3 The Telecommunications Industry Today

- Home
- Office
- Travel for business
- Travel for vacation
- Entertainment for the home
- Entertainment in publicly accessible areas: amusement parks and movie theaters
- Education at home, in the school, in museums

Since the late 1990s, the telecommunications industry has struggled to find new services to sell to subscribers—there are only so many different versions of caller identification one can sell. A user can now see a movie on a computer or a wireless handset. But who cares, when I can see a movie on a high-definition-television set? The reality is that the product-marketing people are still working on creating product sets that will entice a person to buy the service.

One should not take lightly the premise I put forth in Chapter 7: A service must be useful in the life of the subscriber. Even the VCR had a use. It introduced the concept of delayed viewing, which meant that users could record their favorite programs for viewing at a later time and date. The VCR did not need to convince viewers to want to watch television, but it enhanced television viewing.

Broadband service encompasses many different technologies. The various enabling technologies need to be brought together in a way that does something of use for the subscriber. The fact that the user can now access the Internet over a wireless handset is meaningless because a few basic issues have yet to be resolved, such as the small display screen on the handset and limited access to the Web. (The mobile Internet is discussed in more detail in my book, *M-Commerce Crash Course*.)

If one could take all of the technologies that can bring broadband information to the user one would still have a difficult time determining what commercially viable service could be brought to market. Let us look at the pieces needed to bring a broadband service to the user. We need:

- Transmission facilities. Finer transmission can be cost effectively brought to the business place today
- High-speed switches exist today
- Network signaling protocols exist today that can carry voice, video, and data
- Video protocols are being standardized today.
- Terminal devices exist today that can display high resolution graphics and video
- Music protocol formats exist and are successfully used on the Internet

Convergence in the broadband market is exactly this. It is the merging of wireless, wireline telephony, satellite, cable TV, data, the Internet, and entertainment to form information businesses. Convergence accounts for both technical and business aspects in the integration of technology and business. The challenge for the telecommunications industry is not the technology but the business aspects of the industry.

If you were to take all the technology pieces I have listed, what services would you deliver to the user? Remember, users will say they want any service. It is easy to say "yes" in a survey. The question is: Will the user pay for the service every month?

The product developer's two favorite questions are: What does the service do? Who will want to pay for the service; who is the customer?

Who will provide the services? What kind of carrier will provide the services? What business model will this carrier follow? Who are the customers and what types of customers are they?

The company that can successfully answer these questions and correctly implement a delivery system for a new service will thrive in the new economy.

SUMMARY

Broadband services appear to be the ultimate goal for all service providers. Broadband technologies have crossed the wireless and wireline industries. Broadband is the latest "buzz word" in financial circles. Broadband sounds "high tech." Broadband will enable the users of multimedia to interact with other users, in real time. Furthermore, protocol work in the arena of Multi-Protocol Label Switching (MPLS) will allow different broadband networks to communicate with one another.

The telecommunications and information industry is at the brink of change once again. It is resetting itself and is preparing for the introduction of broadband services. As the market stabilizes, a great deal needs to be done within the financial and telecommunications communities to bring technology and business together to deliver broadband services to market successfully.

APPENDIX A

ACRONYMS, DEFINITIONS, AND TERMINOLOGY

1G The first cellular systems, which did not support roaming between networks or even within networks.

2G Refers to the second generation of cellular, which introduced digital technology

2.5G Refers to the next generation of cellular, two and a half, which introduced Internet access.

3G Refers to the third generation of cellular, which theoretically introduces high speed data and additional Internet based services.

3GPP Third Generation Partnership Project; an organization comprised of global standards organizations. Some of these organizations are: ANSI (American National Standards Institute), ETSI (European Telecommunications Standards Institute), TTA of Korea (Telecommunications Technology Association), TTC of Japan (Telecommunications Technology Committee of Japan), and other interested parties. The list may have grown since this books original authorship. This organization focuses on the global harmonization of GSM, EDGE, GPRS, and other narrowband digital technologies. This group is not seeking to make one all encompassing standard, which would require everyone to set aside current business interests and investments, but seeks a level of compatibility between these standards.

3GPP2 Third Generation Partnership Project 2, is a another global effort to seek some level of either comprise or harmonization between the wideband digital technologies, CDMA and W-CDMA.

24x7 A term that refers to one being "on duty" or available for support 24 hours a day, 7 days a week.

802.11 The IEEE (Institute of Electrical and Electronics Engineers) standard for FDDI (Fiber Distributed Data Interface).

A-Law The PCM companding standard used in the European telecommunications community and other areas outside of North America and some areas of South America.

Acceptance Testing The final stage of testing a service provider will subject a telecommunications device, network element, or network prior to turning the system on for full blown commercial service. The acceptance test criteria are always set down in the contract between the vendor and the service provider.

Access link (A-link) Used for Switch-STP signaling connections and STP-HLR.

Access Network Portion of a public switched network that connects access nodes to individual subscribers.

Access Service Area A geographic area established for the provision and administration of communications service. An access service area encompasses one or more exchanges, where an exchange is a unit of the communications network consisting of the distribution facilities within the area served by one or more end offices, together with the associated facilities used in furnishing communications service within the area.

Access Tandem (1) A switching system that concentrates and distributes traffic for interLATA traffic originating or terminating within a LATA (local access and transport area). An access tandem also can provide equal access for nonconforming end offices. (2) An exchange carrier (EC) switching system that provides a traffic concentration and distribution function for interexchange traffic originating or terminating within an access service area.

Adaptive DPCM (Adaptive Differential Pulse Code Modulation) Adaptive DPCM (also known as ADPCM) is considered an improvement over DPCM. ADPCM is capable of varying the assignment of the 4 bits to meet different volume changes. For example, if multiple and successive voice samples were very wide apart, the differential typically described by 4 bits could not keep pace with the actual change. The ADPCM software algorithm is capable of varying the number of bits being used in the sampling. This technique can help reduce quantizing noise from loud signals.

Add/Drop Multiplexer (ADM) A device that demultiplexes (drops) and multiplexes (adds) information being transmitted.

Address Signals These signals convey call destination information or the digits dialed by the calling party. There are several types of address signaling, including Dial Pulse, Dual-Tone Multi-Frequency (DTMF), and Multi-Frequency (MF).

Advanced Intelligent Network (AIN) A telecommunications network capable of providing advanced services through the use of centralized databases that can provide call processing and routing. AIN systems are capable of providing enhanced services that can be used on wireless and wired networks.

Alerting Signals These signals alert the user of an incoming call. This is the ringing the user hears, also known as power ringing in the wireline world.

Amateur Satellite Service This satellite service is for radio amateur use in carrying out technical investigation and learning about intercommunications.

American National Standards Institute (ANSI) A non-profit organization that coordinates voluntary standards activities in the United States. The institute represents the United States in two major telecommunication organizations: the International Standards Organization (ISO) and the International Electrotechnical Commission (IEC).

American Standard Code for Information Interchange (ASCII) A widely accepted standard for data communications that uses a 7-bit digital character code to represent text and numeric characters. When companies use ASCII as a standard, they are able to transfer text messages between computers and display devices regardless of the device manufacturer.

Analog Signal A signal that is modified in a constant fashion, such as voice or data.

Answer Supervision/Answer Signal The signaling state of a circuit that indicates idle or busy, on-hook or off-hook status. The signaling state may be indicated in various ways depending on the signaling system.

Applications Service Provider (ASP) The current (late 1999 to date) way of describing an ESP.

Architectural Switching Plan This would include handoff methodology, anchor switching design, switching selection points, and a routing plan. Efficient routing of calls or data packets based on network efficiency or business arrangements. Route diversity is a major concern for many service providers. But there is a dollar cost to this.

Area Code A three-digit number that identifies the home area of a telephone. In North America, the NPA (Numbering Plan Area) represents the Area Code.

Asymmetric Digital Subscriber Line (ADSL) Modems attached to twisted-pair copper wiring, which transmit from 1.5 Mbps to 9 Mbps downstream (to the subscriber) and from 16 kbps to 800 kbps upstream, depending on line distance.

Asynchronous Transfer Mode (ATM) ATM is a backbone signaling protocol designed to interconnect networks via the asynchronous transmission of information.

Attenuation The decrease in power of a signal, energy, light, or radio signal. This decrease can occur either as a fractional value or completely.

Authentication A process during which information is exchanged between a communications device (typically a mobile phone) and a communications network that allows the carrier or network operator to confirm the true identity of the unit. This inhibits fraudulent use of the mobile unit. It is also the process of user identity confirmation. Identity confirmation can involve checking handset or terminal device identity by interpreting "secret" keys or data messages. If the data keys or data messages have been altered or do not show a specific format, the call will not be completed.

Authentication Center (AC) A standard cellular and PCS carrier database that contains information to authenticate a user.

Automatic Number Identification (ANI) The number that provides the billing number of the line or trunk that originated a call. It is a charge number used to support exchange, access, and billing. This number may or may not be identical to the Calling Party Number.

Backbone A common distribution channel that carries analog or digital telecommunications signals for many users. It may also be used to refer to the central distribution cable from an interface.

Backhaul or Back Haul This term refers to transmission systems that carry traffic to its destination and back to the originating point. The word is both a noun and verb.

Bandwidth The amount (width) of a radio frequency (in Hertz) that can be modulated to transfer information.

Bandwidth Allocation This is the process of assigning bandwidth to users and applications.

Bandwidth on Demand This is the real time and dynamic allocation of bandwidth; whenever the users request it.

Baseband Transmission The transmission of a single signal over a transmission media.

Basic Exchange Telecommunications Radio Service (BETRS) The first wireless local loop technology application. The old Bell System used BETRS to extend basic service to those rural areas that otherwise could not be cost effectively reached using wireline methods. The telephone companies used available UHF and VHF common carrier and private radio frequencies. BETRS may still be used in the most remote places in the United States.

Basic Rate Interface (BRI) In ISDN, the network interface that provides 144 kbps information transfer as defined in ANSI Standard T1.607.

Basic Service This is an old Bell System term to reference Plain Old Telephone Service (POTS); i.e., voice service with no fancy features like call forwarding or call waiting. However, it has evolved to mean anything that a telecommunications carrier calls basic service.

Bearer In the communications industry, a transmission channel used to carry data. For example, ISDN uses 64-kbps bearer channels to carry data.

Billing System A system that processes the records of a given occurrence of a call or some other measurable event, the identity of the originating party, the identity of the destination party, and the time length of the call. This system must also apply rating during the processing of the data for the rendering of a bill to the subscriber.

Bit The smallest part of a digital signal, typically called a data bit. A bit typically can assume two levels, either a zero (0) or a one (1).

Bit Error Rate (BER) A measurement used to determine the quality of a digital transmission channel. BER measures the ratio of bits received in error compared to the total number of bits transmitted.

Blown Fiber This is an interesting way of installing fiber in already buried and established empty conduits. Air is used to "blow" the fiber strands down the conduit. This method of installation is way of shifting one's capital dollars; install empty conduit and then install fiber when you need it.

Bridge A data communications device that connects two or more networks and transmits information between the networks.

Broadband Typically refers to voice, data, and/or video communications at rates greater than wideband communications rates (1.544 Mbps).

Broadband Integrated Services Digital Network (B-ISDN) A digital network with ATM-switching operating at data rates in excess of 1.544 or 2.048 Mbps. ATM enables transport and switching of voice, data, image, and video over the same infrastructure.

Broadcast Messaging Messaging between users of telecommunications networks. Typically, broadcast messaging is between one user and many users; that is, a relationship of one originator to multiple recipients.

Broadcasting Satellite Service A service that allows sound and visuals to be received by individuals or communications via satellite.

Broadcasting Service A service in which the transmissions are intended for direct reception by some consumer group, generally the public at large.

Bursty Data Data rates that fluctuate widely with no predictable pattern.

Business to Business Also known as B2B. The B2B relationship describes the relationship between two or more businesses selling services to one another. Suppliers of small parts to an automobile manufacturer like General Motors would be one example of a B2B relationship. Another example would be the supplier of pencil erasers to the pencil manufacturer. One can take the supplier of ink to the newspaper publisher or to the magazine publisher (news is still supplied to people on paper). Today, the subdivision of relationships has also resulted in the B2SB, Business to Small Business relationship.

Business to Consumer Also known as B2C. The B2C relationship is the one the average consumer is familiar with; retailers selling products online. Consider this online catalogue shopping.

Business to Government Also known as B2G. The B2G relationship is a new one that is growing over the Internet. This relationship is about the business community doing business with sectors of the government. The government, whether local, state, national or international, is the single largest customers of goods and services. To many in the telecommunications business, the government is the single largest customer of telecommunications goods.

Busy Hour A time-consistent hour in a specific measurement period when the total load offered to a group of trunks, or network of trunks, or a switching system, is greater than at any other time-consistent hour during the same measurement period.

Buying Behavior Buying behavior refers to the different types of purchasing based on the involvement of the buyer and the degree of brand differentiation. There are four types of buying behavior:

- *Complex Buying Behavior* When a consumer is highly knowledgeable of a product and its competing brands and makes a purchase based on this body of knowledge the behavior is known as Complex Buying Behavior.

- *Dissonance-Reducing Buying Behavior* This type of buying behavior refers to the situation in which a consumer makes a purchase and then discovers things wrong about the purchase. The consumer becomes so aware of the problems with the product that they begin seeking information justifying their decision. Usually this occurs when the product purchased is very expensive.
- *Habitual Buying Behavior* Consumers often buy specific product brands out of habit.
- *Variety Seeking Buying Behavior* Consumers that frequently switch brand for the sake of change, boredom, feeling of the moment or for any kind of reason demonstrate a buying behavior known as Variety Seeking Buying Behavior.

Bypass Bypass originally referred to the bypassing of the Incumbent Local Exchange Carrier (ILEC) by the customer. Now it refers to whomever is being bypassed by the customer.

Cable Television (CATV) *See* Community Access Television.

Call Delivery (CD) A call routing process in the wireless telecommunications sector that permits a subscriber to receive calls to his or her Directory Number while roaming.

Call Detail Recording (CDR) This is a telecommunications system's ability to collect and record detailed information on all outgoing and incoming calls.

Call Forwarding-Busy (CFB) A call routing service that permits a called subscriber to have the system send incoming calls addressed to the called subscriber's directory number to another directory number (forward-to number) or to the called subscriber's designated voice mail box, when the subscriber is engaged in a call or service.

Call Forwarding-Default (CFD) A call routing service that permits a called subscriber to send incoming calls addressed to the called subscriber's directory number to the subscriber's designated voice mail box or to another directory number (forward-to number), when the subscriber is engaged in a call, and does not respond to paging, does not answer the call within a specified period after being alerted, or is otherwise inaccessible (including no paging response, the subscriber's location is not known, the subscriber is reported as inactive).

Call Forwarding-No Answer (CFNA) A call routing service that permits a called subscriber to have the system send incoming calls addressed to the called subscriber's directory number to another directory number (forward-to number) or to the called subscriber's designated voice mail box, when the subscriber fails to answer, or is otherwise inaccessible (including no paging response, the subscriber's location is not known, the subscriber is reported as inactive, Call Delivery not active for a roaming subscriber, Do Not Disturb active, etc.).

Call Forwarding-Unconditional (CFU) A call routing service that permits a called subscriber to send incoming calls addressed to the called subscriber's directory number to another directory number (forward-to number) or to the called subscriber's designated voice mail box. If this feature is active, calls are forwarded regardless of the condition of the subscriber's active directory number state.

Call Processing Steps that occur during the duration of a call. These steps are typically associated with the routing and control of the call.

Call Progress Signals Voice band tones and announcements used to inform a calling end-user or operator of the progress or disposition of a call. Examples include busy tone, voice announcement, special information tones, and audible ringing. The tones or announcements can be used after a number has been dialed and until the called telephone is answered or the attempt is abandoned.

Call Routing In circuit-switching, this is the process of determining the path of a call from the point of origination to the point of destination.

Call Transfer (1) A call-handling feature that transfers a call from one station or extension to another. (2) Call transfer service enables a subscriber to transfer an in-progress established call to a third party. The call to be transferred may be an incoming or outgoing call.

Call Waiting (1) A telephone call processing feature that notifies a telephone user that another incoming call is waiting to be answered. This is typically provided by a brief tone not heard by the other callers. Some advanced telephones (such as GSM mobile telephones) are capable of displaying the incoming phone number of the waiting call. (2) A call routing service that provides notification to a controlling subscriber of an incoming call while the subscriber's call is in the two-way state. Subsequently, the controlling subscriber can either answer or ignore the incoming call. If the controlling subscriber answers the second call, it may alternate between the two calls.

Calling Name Identification Presentation (CNaIP) A call processing service that provides the name identification of the calling party to the called subscriber.

Calling Name Identification Restriction (CNaIR) A call processing service that restricts the presentation of the calling party's name to the called subscriber.

Calling Number Identification (CNI) A feature that allows a telephone customer to view the telephone number of the person who is calling. A related service called Calling Number Identification Restriction (CNIR), allows the caller to inhibit the display of the calling telephone number when placing a call.

Calling Number Identification Presentation (CNIP) A call routing service that provides the number identification of the calling party to the called subscriber. One or two numbers may be presented to identify the calling party.

Calling Number Identification Restriction (CNIR) A call processing service that restricts presentation of that subscriber's Calling Number Identification (CNI) to the called party.

Calling Party Number (1) In the Integrated Services Digital Network (ISDN) Q.931 and Signaling System 7 protocols, an information element that identifies the number of an originating party. (2) A set of digits and related indicators that provide numbering information related to the calling party. It is the identification number of the party originating a call.

CCS (Centi [Hundred] Call Seconds) A measurement of telephone usage traffic used to express the average number of calls in progress, the average length of a call in a given period, or the average number of devices used.

Cell Site A transmitter–receiver tower, operated by a wireless carrier (typically cellular or PCS), through which radio links are established between a wireless system and mobile and portable units.

Central Office A term used to describe local switches used by the local telephone companies. The term is synonymous with End Office.

Centrex A service for business customers that shifts the functions usually associated with a Private Branch eXange (PBX) on a customer's premises to a central-office switching system.

Channel Reuse Refers to the practice of independently using radio channels that have the same radio frequency to cover different coverage areas.

Chat Rooms Chat rooms have been both a blessing and a curse to the Internet community. Pedophiles and other morally twisted individuals have taken to the chat room to wreak havoc on people's lives. I need say no more about this. On the upside, the chat room has become more than a place for people to meet and chat, it has become a place where celebrities (movie stars, television stars, famous folks, and authors) can meet fans and promote movies, books, television shows, and other products.

Coaxial Cable A transmission line consisting of an inner conductor surrounded first by an insulating material and then by an outer conductor, either solid or braided. The mechanical dimensions of the cable determine its characteristic impedance.

Common Channel Signaling (CCS) Also known as "out-of-band" signaling; describes a scheme in which the physical path of the content of the call is separated from the path of the information used to set up the call (signaling information).

Competitive Access Providers (CAPs) An alternative local exchange carrier that competes with the existing incumbent and dominant local exchange carrier.

Community Access Television (CATV) Also known as cable TV; represents a popular form of sending entertainment programming into households via a physical transmission system (e.g., coaxial cable, DS1, etc.). Years ago, CATV enabled homes in remote areas to receive limited television programming when wireless transmission signals could not reach such areas.

Competitive Local Exchange Carrier (CLEC) A description of the new carriers (as encouraged by the Telecommunications Act of 1996) that are competing in the local loop marketplace.

Concentration Concentration is a telephony switching concept. When one designs a telephone network the cost of installing trunking facilities to handle simultaneous the telephone traffic of all users would be prohibitive. Therefore one makes an assumption about the number of users who will actually make a call in any given period of time (typically on a one hour period). This assumption then is used as a design parameter for the number of trunks. The result is a system that concentrates the traffic onto a number of facilities; it is not a one to one relationship. In other words, rather than one facility per person it might be one facility per 3 people.

Conference Calling (CC) A call routing service that provides a subscriber with the ability to have a multiconnection call, i.e., a simultaneous communication between three or more parties (conferees).

Content Content is a new name for the information transmitted by the telecommunications network. Content refers to multiple forms of information transmitted over the network.

Continuously Variable Slope Delta Modulation (CVSD) There will be instances where all one will need is a single bit to describe a sample. In those cases where there is only one bit involved, one can send lots of samples about a small signal in bandwidth pipe capable of handling large volumes of data. Unfortunately, this also means that one is restricting oneself to signals that are not loud. CVSD looks at each and every individual bit and only sends information about the changes in the rate of change.

Control Signals Signals used for special auxiliary functions that are beyond a service provider's network. These signals communicate information that enables or disables certain types of calls. One example is call barring.

Convergence Addresses the technical and business aspects of integration of traditional technology and business with newer and more advanced technologies and business methodologies.

Country Code A one-, two-, or three-digit number that identifies a country or numbering plan to which international calls are routed. The first digit is always a world zone number. Additional digits define a specific geographic area, usually a specific country.

Cross Connect A cross connect is an organized place where telecommunications systems' wires meet and are connected to one another. When telecommunications equipment is installed in a building, the wires connected to that equipment are run to a single location. This location is a common point in which all equipment, T1s, DS3s, CPE, and other kinds of telecommunications equipment can be interconnected to one another. Consider it a junction box, which electricians use to act a point of re-routing and a place to connect wires to other wires that are running to a different place in the house. If the cross connect did not exist, then transmission systems form the outside would have to be run from the street all the way up through the building. When the system is disconnected one would have to then pull all of the wire out of the building. The most organized way of connecting customers in a building is a by having all systems meet at a common point. This would also enable changes to occur in a more organized fashion.

Customer Care System A customer profile database system used to support customer complaints, add new subscribers, and remove subscribers; it also contains customer profile information.

Customer Premises Equipment (CPE) All telecommunications terminal equipment located on the customer's premises, including telephone sets, PBXs, data terminal, and customer-owned coin-operated telephones.

Data Compression A technique for encoding information so that fewer data bits of information are required to represent a given amount of data. Compression allows the transmission of more data over a given amount of time and circuit capacity. It also reduces the amount of memory required for data storage.

Data Terminal Equipment (DTE) In a data communications network, the data source, such as a computer, and the data sink, such as an optical storage device. (*See also*: data sink, data source, network channel terminating equipment, channel service unit, data service unit.)

Data Warehouse An information management service that stores, analyzes, and processes information derived from transaction systems.

Database A collection of interrelated data stored in computer memory with a minimum of redundancy. Database information held in a computer-accessed memory usually is subdivided into pages, with each page accessible to all users unless it belongs to a closed user group.

Dedicated Circuits A circuit designated and reserved for a specific use or customer.

Demultiplexing A process applied to a multiplexed signal for recovering signals combined within it and for restoring these individual signals.

Dense Wave Division Multiplexing (DWDM) The high capacity version of Wave Division Multiplexing (WDM).

Dial-Line A two-wire, line-side connection from an LEC end office. This connection is like the connections used for business and residential lines. This connection may be used on a one-way or two-way basis. Dial-line connections enable the MSC to access any valid telephone number.

Dialing Parity A company not an affiliate of a local phone company is able to provide phone services in such a manner that customers have the ability to route their calls automatically without the use of any access code.

Differential Pulse Code Modulation (DPCM) Voice has a dynamic range but it varies slowly. Even though the voice signal can vary across a wide volume range it does so in small increments and slowly. This also means that for the same level of accuracy fewer data bits are needed to describe the difference between one sample and another sample than the number of bits needed to describe the full range. This observation has resulted in some old transmission designs that only support 4-bit sampling; DPCM supports 4-bit modulation as opposed to PCM's 8 bit modulation.

Digital Loop Carrier (DLC) Transmission equipment used to multiplex and demultiplex multiple channels over a large bandwidth 4 wire, twisted pair system. The DLC multiplexes the system into 64 kbps blocks. The DLC eliminates the need for large numbers of pairs of wires. DLCs were especially helpful for ISDN deployments

Digital Signal A signal that has a limited number of discrete states, usually two. In contrast, an analog signal varies continuously, and has an infinite number of states.

Digital Signal 0 (DS-0) A 64-kbps digital representation of an analog voice equivalent.

Digital Signal 1 (DS-1) Twenty-four voice channels packed into a 193-bit frame and transmitted at 1.544 Mbps. The unframed version, or payload, is 192 bits at a rate of 1.536 Mbps.

Digital Signal 2 (DS-2) Four T-1 frames packed into a higher-level frame transmitted at 6.312 Mbps.

Digital Signal 3 (DS3) Twenty-eight T-1 frames packed into a higher-level frame transmitted at 44.736 Mbps.

Digital Subscriber Line (DSL) A two-wire, full-duplex transmission system that transports user data between a customer's premises and a digital switching system or remote terminal at 144 kbps.

Digital Television A device that receives broadcast digitally formatted television signals. Such devices display programming with far greater resolution than current television sets.

Direct Distance Dialing (DDD) A telephone service which allows a user dial a long distance call without operator assistance. This is a common feature today. However, many years ago this capability was considered a special capability for telephone switches.

Direct Inward Dialing (DID) A PBX or Centrex feature that enables completion of an incoming call directly to an extension station without operator assistance. Direct inward dialing is used in voice mail and radio paging systems, also.

Disconnect Signal An on-hook signal indicating the connection is being cleared. The signal responding to a disconnect signal, but applied in the direction opposite to the direction of propagation of the disconnect signal, may also be considered a disconnect signal.

Distinctive Ringing A feature that enables a multiplicity of subscriber numbers (on a single line) to be identified by different ringing patterns.

Do Not Disturb (DND) A call-processing feature that prevents a called subscriber from receiving calls. When this feature is active, no incoming calls will be offered to the subscriber. DND also blocks other alerting, such as the Call Forwarding-Unconditional abbreviated (or reminder) alerting and Message Waiting Notification alerting. DND makes the subscriber inaccessible for call delivery.

Domain Name The unique name that identifies an Internet site.

Downlink The portion of a communication link used for transmission of signals from a satellite or airborne platform to a terrestrial terminal.

Dual Tone Multi-Frequency (DTMF) A means of signaling that uses a simultaneous combination of one of a lower group of frequencies and one of a higher group of frequencies to represent each digit or character. These frequencies are tones.

E-1 European basic multiplex rate that packs thirty voice channels into a 256-bit frame and is transmitted at 2.048 Mbps.

E-Carrier A 10-MHz wireless carrier also known as a Personal Communications Service (PCS) carrier.

E-Commerce Electronic Commerce is the process of doing business over the Internet. Companies and individuals transact business over the Internet.

Earth Exploration Satellite Service Service that allows observation of the Earth for various purposes such as atmospheric and geological study.

Effective Radiated Power (ERP) Defined by the FCC as the electromagnetic energy radiated from an antenna measured in watts.

Electronic Mail (E-mail) Messages, usually text, sent from one person to another via computer.

Emergency Services Access Point An emergency services network element that is responsible for answering emergency calls.

Encryption A process of protecting voice or data information from being obtained by unauthorized users. Encryption involves the use of a data processing algorithm (formula program) that employs one or more secret keys that both the sender and receiver of the information use to encrypt and decrypt the information. Without the encryption algorithm and key, unauthorized listeners cannot decode the message.

End Office (EO) A switching system that terminates station loops and connects the loops to each other and to trunks.

Engineer, Furnish, and Install (EF&I) A way vendors sell their products. In other words, vendors will EF&I the product for the customer, rather than the customer doing the install themselves.

Engineered Capacity The highest load level at which service objectives are met for a trunk group or a switching system.

Enhanced Service Provider (ESP) An old term (1990s) used to describe a company that provides enhanced or value-added services to end users. This eventually evolved to describe companies that provided other services to other carriers because the ESPs could not break into the local retail business; wholesale to carriers became the alternative.

Equal Access An exchange carrier service that gives a customer an equal choice of trunk-side access to public switched interexchange carrier telephone networks in terms of such items as dialing plan and transmission quality. Another term for this is Feature Group D.

Erlang Amount of voice connection time with reference to one hour. For example, a 6-minute call equals .1 Erlang.

Ethernet A transmission protocol for packet-switched Local Area Networks (LANs). Ethernet is a registered trademark of Xerox Corporation.

Exchange The typical shorthand term used to identify a telephone switching center.

Exchange Access The offering of access to telephone exchange services or facilities for the purpose of the origination or termination of telephone toll services.

Exchange Carrier A telephone company, generally regulated by a state regulatory body, which provides local (intraLATA) telecommunications services.

Exchange to Exchange Also known as X2X. The X2X relationship is the linkage of multiple B2B relationships or marketplaces. X2X e-commerce is the next logical step beyond B2B or B2SB. Companies are able to purchase supplies and products at competitive prices. X2X can be likened to a farmers' market; where large food distribution companies bid for farmers' products. Manufacturers and vendors of all kinds seeking to purchase supplies and services over the Internet. Steel is an example of a product that was often sold between companies and countries via a network of dealers. Now steel can be bought and sold over an Internet based exchange. X2X e-commerce could ultimately result in lower prices to the consumer because of the lower costs to the retail outlets and to the distributors (i.e., the middleman).

Facilities The transmission parts (elements) of a service provider. Sometimes used in more general terms to describe buildings and utilities.

Facsimile Also known as fax. This is a form of telegraphy that supports the transmission of fixed images to some form of fixed medium, like paper.

Facsimile Machine A facsimile (FAX) machine transmits a hard copy (paper) document over standard twisted pair copper to another FAX machine waiting to receive it. The FAX machine scans the document and transmits the image over its modem to a receiving FAX machine's modem.

Fax Mail (FxM) A communications service that provides a subscriber with fax mail, which include the ability to store faxes received, or forward recorded faxes, based on a number of subscriber-set parameters.

Fiber To The Home (FTTH) A communication network where an optical fiber runs from the telephone switch to the subscriber's premises or home.

Fiber To The Neighborhood (FTTN) A communications network where an optical fiber runs from a switch to a given point in a neighborhood of homes.

Fiber Mile A fiber mile refers to the fibers themselves. Therefore, if you have one fiber strand and the run is 1 mile long then you have 1 fiber mile. On the other hand if you have 5 strands each traveling 1 mile, then you have 5 fiber miles.

Fiber Route Mile A fiber route mile refers to the total distance a fiber strand is traveling. If there are 20 strands of fiber and the run is 1 mile long then you have 1 route mile. If there are 100 strands of fiber and the run is 1 mile long then you still have 1 route mile.

Firewall A term that refers to a physical and electronic method of protecting a computer from outside attack. This protection involves hardware and software.

Fixed Satellite Service A radio communication service that addresses communication between earth stations at specified fixed points via one or more satellites (e.g., Intelsat).

Flat Rate Price setting principles for a service provider that wishes to charge the same fee for calls regardless of the number of calls made or the duration of each call. Usually flat rates are single monthly or periodic charges.

Flexible Alerting (FA) A call processing service that causes a call to a pilot directory number to branch the call into several legs to alert several termination addresses simultaneously. The mobile telephones in the group may be alerted using distinctive alerting. Additional calls may be delivered to the FA pilot directory number at any time. The first leg to be answered is connected to the calling party. The other call legs are abandoned.

Foreign Agent (FA) A router that resides in a roaming network.

Foreign Exchange (FX or FEX) Telecommunications trunk lines that connect directly to a foreign telephone companies switching system (exchange).

Four-Wire Circuits A physical path in which four wires are represented to the terminal equipment. This path allows for simultaneous transmission and reception. Two wires are used for transmitting in one direction, and the other two wires are used for transmitting in the other direction.

Fractional T-1 Fractional T-1 refers to data transmission speeds between 56 kbps and 1.544 Mbps in a single full T-1.

Frame Relay An access standard defined by the ITU standards body. Frame Relay services are telecommunications services that employ a form of packet switching analogous to a streamlined version of X.25 networks. The data packets are in the form of "frames." These frames are variable in length.

Frame Switching Refers to devices that forward information frames based on the frame's layer 2 address. Frame switching can be done in two ways, via either cut-through or store-and-forward information switching.

Frequency The rate at which an electromagnetic waveform varies in period. The period is a single energy cycles in a given time period (usually expressed in cycles per second or Hertz). Light is measured in packets per second. Data is measured in bits per second. Nevertheless, they are all representations of units of energy per second.

Frequency Division Multiplexing (FDM) A technique in which available transmission bandwidth of a facility is divided by frequency into narrower bands. Each band is used for a separate voice or data transmission channel. In this manner multiple conversations can take place over a single transmission facility.

Full-Duplex Transferring of voice or data in both directions at the same time. This becomes confusing in a TDMA system because information is reconstructed to allow transfer of voice information in both directions at the same time although actual transmission does not occur simultaneously.

Full Motion Video A multimedia transmission. Images are sent and displayed in real time and motion is continuous (as opposed to jerky, shaky movements).

Gateway A device or facility that enables information to be exchanged between two dissimilar computer systems or data networks. A gateway reformats data and protocols in such a way that the two systems or networks can communicate.

Global Title In the Signaling System 7 protocol, an address, such as customer-dialed digits, which does not contain explicit information to enable routing in a signaling network and, therefore, requires the signaling connection control part translation function.

Global Title Translation (GTT) In SS7, a procedure that translates a Global Title into a known address that allows message routing in the signaling network.

Gigabit Ethernet (GE) Also known as IEEE standard 802.3z. GE is orders of magnitude higher than regular Ethernet, which operates in the 10 Mbps through 100 Mbps data rate range.

GOS (Grade of Service) An estimate of customer satisfaction with a particular aspect of service. It also refers to the probability that a call will fail due to the unavailability of links or circuits.

GR 303 A specification originally developed by Bellcore, now known as Telcordia. GR 303 is a specification that defines how a digital loop carrier (DLC) system will interface with T1 transmission system.

Half–Duplex The ability to transfer voice or data information in either direction between communications devices but not at the same time. The information is transmitted on one frequency and received on another frequency.

Handoff The process of reassigning subscriber handsets to specific radio channels as the handsets move from cell site to cell site.

Hard Handoff Hard handoff is a "break-before-make" form of call handoff between radio channels. In this scenario, the mobile handset temporarily (time measured in milliseconds) disconnects from the network as it changes channels. The radio protocols, AMPS, TDMA, and GSM support only hard handoff.

High Capacity Voice (HCV) As the name implies HCV is focused on providing high quality voice at 8,000 bits per second, theoretically a quality level higher (better) than plain old PCM. HCV expands on the principle of vector coding techniques used in VQC. HCV expands on VQC by taking many more forms of waveform coding that model human vocalization. Human vocalization is comprised of numerous sounds, all generated by things other than vocal cords. The vocal process is comprised of lungs, vocal cords, lips, sinus cavities, tongue, teeth, etc.

High Data Rate Digital Subscribe Line (HDSL) Modems on either end of one or more twisted-pair wires that deliver T-1 or E1 speeds. At present T-1 requires two lines and E1 requires three. *See* SDSL for one line HDSL.

High Level Data Link Control (HDLC) A bit-oriented communications protocol in which control codes differ according to their bit positions and patterns.

High-Usage Trunk Group A transmission facility used only for routing large volumes of traffic to a single point or set of points.

Home Agent (HA) A router that resides in the home network. The HA support the transmission of IP datagrams to other routers or another agent. The HA could reside in a home based Internet Service Provider's (ISP's) network.

Home Location Register (HLR) A standard cellular and PCS carrier database that contains all user profile information and supporting routing information.

Hybrid Fiber–Coax A system (usually CATV) where fiber is run to a distribution point close to the subscriber and then the signal is converted to run to the subscriber's premises over coaxial cable.

Inband Signaling A type of signaling in which the frequencies or time slots used to carry the signals are within the bandwidth of the information channel.

Incumbent Local Exchange Carrier (ILEC) A telephone service carrier operating in the local loop market prior to the Telecommunications Act of 1996 and the divestiture of the AT&T Bell System. In other words, it was the local telephone company most people grew up with.

Information Service The offering of a capability for generating, acquiring, storing, transforming, processing, retrieving, utilizing, or making available information via telecommunications, which includes electronic publishing, but does not include any use of any such capability for the management, control, or operation of a telecommunications system or the management of a telecommunications service.

Integrated Services Digital Network (ISDN) A structured all-digital telephone network system that was developed to replace (upgrade) existing analog telephone networks. The ISDN network supports advanced telecommunications services and defined universal standard interfaces used in wireless and wired communications systems.

Interconnection The connection of telephone equipment or communications systems to the facilities of another network. The FCC regulates interconnection of systems to the public switched telephone network. *See also:* bypass.

Interexchange carrier (IXC) A carrier company in the United States, including Puerto Rico and the Virgin Islands, that is engaged in the provisioning of interLATA, interstate, and/or international telecommunications over its own transmission facilities or facilities provided by other interexchange carriers.

Interexchange Trunks Transmission facilities used to support communications between switching centers (LEC switches) and the interexchange carrier (IXC).

InterLATA Service Telecommunications between a point located in a local access and transport area and point located outside such area.

International Carrier (INC) A carrier authorized to provide interexchange communications services outside World Zone 1 using the international dialing plan; however, the carrier has the option of providing service to World Zone 1 points outside the 48 contiguous United States.

International Gateway Facilities (IGFs) Transmission facilities used by International Gateway Switches. An International Gateway Switch is used by the long distance (interexchange) carrier to interface with international telecommunications networks.

International Routing Code A three-digit code within the North American Numbering Plan, beginning with 1, which classifies international calls as requiring either regular or special handling.

International Telecommunications Union (ITU) A European telecommunication standards body. Counterpart of ANSI.

Internet The major network running the Internet protocol across the United States and Canada. The Internet consists of more than 30,000 hosts and includes sites at universities, research laboratories, corporations, and nonprofit agencies.

Internet GPRS Support Node (IGSN) Combines the functions of the serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN). The IGSN also serves to connect the radio network to the IP network.

Internet Service Provider (ISP) A vendor that provides access to the Internet and the World Wide Web.

Intranet A private network inside a company or organization that not only serves as the company information network but also provides access to the public Internet. The intranet appears like another server to the Internet.

Intersatellite Service Provides links between artificial earth satellites.

Inverse Multiplexing The process of splitting a high-speed channel into multiple signals, transmitting the multiple signals over multiple facilities operating at a lower rate than the original signal, followed by a process of recombining the separately transmitted portions into the original signal at the original rate of speed.

Last Mile Last mile is a term used to refer to the twisted copper pair leading to the home or business. The term is not precise and is not meant to be precise. The term describes a relationship rather than technology or network architecture. The term last mile was created after the divestiture of the AT&T Bell System (1984) to describe the connection between the ILEC central office and its customer.

Layer 1 Layer 1 is an OSI term used to describe the physical means of transporting data/information.

Layer 2 Layer 2 is the OSI term used to describe the procedures (network error correction, etc.) and protocols for operating the communications channels.

Layer 3 Layer 3 is the OSI term used to describe how data is communicated between systems and network elements. Layer 3 addresses routing methodologies.

Layer 4 Layer 4 is the OSI term used to describe how information data/information is exchanged and managed within and between networks.

Layer 5 Layer 5 is the OSI term used to describe how the actual information exchange is managed by the users.

Layer 6 Layer 6 is the OSI term used to describe how the information is presented to the user.

Layer 7 Layer 7 is the OSI term used to describe the applications being presented to the user.

Local Access and Transport Area (LATA) As designated by the Modification of Final Judgment, an area in which a local exchange carrier is permitted to provide service. It contains one or more local exchange areas, usually areas with common social, economic, or other interests.

Local Area Network (LAN) A private network offering high-speed digital communications channels for the connection of computers and related equipment in a limited geographic area. LANs use fiber optic, coaxial, twisted-pair cables, or radio transceivers to transmit signals.

Local Exchange Carrier (LEC) A company that provides telecommunications service within a local access and transport area (LATA).

Local Loop A channel connecting customer equipment to the line-terminating equipment in a central office of the local exchange company. Typically, a loop is a two- or four-wire cable circuit between a vertical main distributing frame appearance in a central office and the point of termination at a customer's premises. The cable from a frame to a cross-connect terminal is called a feeder. The feeder also can be provided over digital loop or analog carrier systems. Digital systems can be served by either wire or fiber optics.

Managed Service Provider (MSP) A modern way of describing the 1980s and 1990s version of the landlord run telecommunications services operation. Landlords of building often provide the telecommunications service to their tenants; think Customer Premise Equipment owned and operated by th elandlord.

M-Commerce Mobile commerce is the process of doing business over the wireless Internet (provided by wireless carriers). Companies and people transact business over the wireless or mobile Internet.

Message Waiting Notification (MWN) A service that informs enrolled subscribers when a voice message is available for retrieval. MWN may use pip tone, an MS indication, or an alert pip tone to inform a subscriber of an unretrieved voice message(s). MWN has no impact on a subscriber's ability to originate calls or to receive calls.

Messaging Delivery Service (MDS) A service that permits pending voice messages to be attempted for delivery to subscribers on a periodic basis until the subscriber acknowledges receipt of the messages.

Mobile Access Hunting (MAH) A call-processing service that causes a call to a pilot directory number to search a list of termination addresses sequentially for one that is idle and able to be alerted. If a particular termination address is busy, inactive, fails to respond to a paging request, or does not answer alerting before a time-out, then the next termination address in the list is tried. Only one termination address is alerted at a time. The mobile telephones in the group may be alerted using distinctive alerting.

Mobile Identification Number (MIN) The 10-digit number that represents a mobile telephones (mobile station) identity.

Mobile Satellite Services (MSS) A communications service that provides communications between mobile earth stations and one or more space stations or between mobile earth stations via one or more space stations. Earth stations can be situated onboard ships, onboard aircraft, and onboard terrestrial vehicles. This service may also be used to detect and locate emergency signals from people in distress.

Mobile Switching Center (MSC) The central switching system used for cellular and PCS networks. The MSC was formerly called the mobile telephone switching office (MTSO).

Mobile Telephone Switching Office (MTSO) A cellular carrier switching system that includes switching equipment needed to interconnect mobile equipment with land telephone networks and associated data support equipment. (*See also* mobile switching center [MSC].)

Modem A contraction of modulator/demodulator. It is a device or circuit that converts digital signals to and from analog signals for transmission over conventional analog telephone lines. Modem also may refer to a device or circuit that converts analog signals from one frequency band to another.

Multifrequency (MF) A type of inband address signaling method in which decimal digits and auxiliary signals are each represented by selecting a pair of frequencies from the following group: 700, 900, 1,100, 1,300, 1,500, and 1,700 Hz. These audio frequencies are used to indicate telephone address digits, precedence, control signals, such as line-busy or trunk-busy signals, and other required signals.

Multiplexer Electronic equipment that allows two or more communications signals to pass over a single communications circuit.

Multiprotocol Label Switching (MPLS) MPLS is an Internet Engineering Task Force (IETF) standard that is being used to speed up IP-based communications. MPLS involves taking a datagram and attaching a tag/label in the packet header. The packet header precedes the packet. The network reads the label and forwards the packet onto the next destination or the final destination. This is akin to how voice calls are routed; a long distance carrier reads only the prefix "1" and the Area Code (NPA); the local telephone company reads the NPA, the first three digits of the telephone and then finally the last four digits.

N+1 This term is often used to refer to network element redundancy. Therefore, one would provision the amount needed for operation plus one extra device.

N-Carrier The predecessor to T-1. N-Carrier is frequency division multiplexed analog carrier.

Narrowband A communications channel of restricted bandwidth, often resulting in degradation of the transmitted signal.

National Number The telephone number identifying a calling subscriber station within an area designated by a country code.

Network (1–*general*) A series of points interconnected by communications channels, often on a switched basis. Networks are either common to all users or privately leased by a customer for some specific application. (2–*antenna coupling*) A network that employs a radio frequency circulator, enabling two separate radio transmitters to use the same antenna at the same time. (3–*balanced*) A network in which the series elements in both legs of the circuit are symmetrical with respect to ground. (4–*bilateral*) A network which is capable of supporting bidirectional communications between itself and other networks. Such a network treats other networks as peer networks in the switching hierarchy; therefore a predetermined process of how to pass and acknowledge calls between networks is necessary.

Network Element A facility, or the equipment, used in the provisioning of a telecommunications service. The term includes subscriber numbers, databases, signaling systems, and information sufficient for billing and collection or used in the transmission, routing, or other provision of a telecommunications service.

Network Interconnection The interconnecting of two more networks to one another.

Network Interface Card (NIC) A circuit card or pack that connects a desktop computer to a larger network of computers. In telecommunications systems, network interface cards connect network devices to other network devices.

Network Operations Center (NOC) A center responsible for the surveillance and control of telecommunications traffic flow in a service area.

Network Planning Network planning is a process that involves understanding the technical needs of the service provider's network and the financial realities of fulfilling the technical requirements. Network interconnection is a component of the planning process that requires a service provider to carefully plan the design and implementation of its network. There is a cost to interconnecting networks, which involves (but is not limited to) network signaling protocols, cost of transmission facilities, routing plans, and cost of network interface units.

Network Signaling The language by which we will communicate with other service providers and by which we will communicate with network elements within your own network.

Next Generation Digital Loop Carrier Transmission equipment used to multiplex and demultiplex channels on fiber optic facilities to neighborhoods or buildings. The last leg or mile is still on twisted pair copper.

Node A node is a point of connection in a network.

Noise (1–*general*) Any random disturbance or unwanted signal in a communication system that tends to obscure the clarity of a signal in relation to its intended use. (2–*ambient*) The acoustic noise that is part of the environment in which a system transducer is located. (3–*atmospheric*) A component of sky noise arising from natural phenomena within the atmosphere, such as a lightning discharge. (4–*broadband*) A noise signal with significant spectral intensity over a band where the upper frequency is many times higher than the noise.

North American Numbering Plan (NANP) A telephone numbering system used in North America that employs 10-digit numbering. The number consists of a three-digit area code, a three-digit central office code, and a four-digit line number.

Notice of Public Rulemaking (NPRM) A term used by the U.S. Federal Communications Commission (FCC) to alert people to a policy position the FCC is considering.

Number Portability An initiative whereby the customer's current phone number can be transferred to other networks, carriers, or service providers.

Numbering Plan Area (NPA) A three-digit code that designates one of the numbering plan areas in the North American Numbering Plan for direct distance dialing. Originally, the format was N0/1X, where N is any digit 2 through 9 and X is any digit. From 1995 on, the acceptable format is NXX.

Off-Hook A signal used on lines and trunks to indicate in-use or request-for-service states. The signal is generated by the switch in a wireline network. The off-hook signal is heard by the calling party and is called dial tone.

Offered Load The total traffic load submitted to a group of servers, including any load that results from retries.

On-Hook (1–*telephony*) A signal used to indicate that a line or trunk is not currently in use and is available for service. The signal is transmitted to a central office when the receiver is placed on its hook. (2–*telephony*) The state of being on-hook.

Open Systems Interconnection (OSI) Model The OSI model is an internationally accepted framework of standards for telecommunications between different systems made by different vendors. The model organizes the telecommunications functions into seven different layers. It allows engineers to isolate and classify telecommunications into discrete functions or activities.

Operations Administration and Maintenance (OA&M) This term refers to managing a network or telecommunications system. Normally one uses OA&M to reference a series of functions that include: network diagnostics, network element management, alarm indications, and performance monitoring.

Operator Services A term traditionally used by wireline telephone companies to refer to services that use a human operator or automated operator to render assistance to customers in the making of collect calls, third-party billed calls, credit card calls, calling card calls, and person-to-person calls.

Optical Fiber A threadlike filament of glass used to transmit digital voice, data, or video signals in the form of light pulses. Multimode step index fiber has relatively low capacity and is seldom used. Multimode graded index fiber is used for low-traffic routes. Single mode step index fiber has high capacity and is the most commonly used type.

Out-of-Band Signaling A type of signaling in which the frequencies or timeslots used to carry the signals are outside the bandwidth of the information channel.

Outpulsing Outpulsing is a wireline telephony term used to refer to the pulsing of telephone number digits from the central office to another switching facility.

Outside Plant The part of a telephone system that is outside the local exchange company buildings. Included are cables and supporting structures. Microwave towers, antennas, and cable system repeaters are not considered to be outside plant equipment.

Packet Data Data transmission that breaks up or sends small packets of data by including the address and sequence number with each packet sent. Packets find their way through a packet switching network that eventually routes them to their destination where they are placed back in sequence by a Packet Assembler/Disassembler (PAD).

Packet Switching A mode of data transmission in which messages are broken into increments, or packets, each of which can be routed separately from a source, then reassembled in the proper order at the destination.

Paging A method of delivering a message, via a public communications system or radio signal, to a person whose exact whereabouts are unknown by the sender of the message. Users typically carry a small paging receiver that displays a numeric or alphanumeric message on an electronic readout; the message could also be sent and received as a voice message or other data.

Paging Audio Tone Signal Tone only, no alphanumeric characters at all. The tone means the individual either called an operator or simply called a predetermined point. There are three types of tone-only protocols: two-tone, three-tone, and five-tone.

Paging Message Service (PMS) A service that permits paging messages to be attempted for delivery to subscribers (via SMS) on a periodic basis until the subscriber acknowledges receipt of the message. Messages may be up to 256 characters.

Password Call Acceptance (PCA) A call screening feature that allows a subscriber to limit incoming calls to those calling parties who are able to provide a valid PCA Password (i.e., a series of digits).

Path Minimization The process of efficient fixed network (the nonwireless portion of the call) routing of wireless call tables in the wireless carrier switches.

Permanent Virtual Circuit (PVC) A virtual circuit that provides the equivalent of a dedicated private line service over a packet switching network between two data terminal devices. The path between the users is fixed. However, a PVC uses a fixed logical channel to maintain a permanent association between the data terminal device stations.

Photonic Switches Switches that use light to carry telecommunications signals within the switch.

Point of Interface (POI) The physical location marking the point at which the local exchange carrier's service ends.

Point of Presence (POP) A physical location established by an interexchange carrier within a LATA for the purpose of gaining LATA access. The point of presence is usually a building that houses switching and/or transmission equipment, as well as the point of termination.

Presubscription A term created in 1984 to describe subscriber subscription to a predetermined Interexchange Carrier. The term is a legacy word from the days of immediate AT&T post-divestiture.

Preferred Language (PL) Provides a telephone service subscriber with the ability to specify the language for network services. This service allows the subscriber to specify service in English, Spanish, French, or Portuguese. Provision will be made for additional languages in the future.

Primary Rate Interface In the ISDN, a channel that provides digital transmission capacity of up to 1.536 Mbps (1.984 Mbps in Europe) in each direction. The interface supports combinations of one 64-kbps D channel and several 16-kbps B channels, or H channel combinations.

Private Branch eXchange (PBX) A private switching system serving an organization, business, company, or agency, and usually located on a customer's premises.

Private-Line Often used to connect the wireless carrier switch to a cell site or to connect two cell sites together. This connection may be two-wire or four-wire analog, DS-1, or DS-3 circuits.

Protocol (1–*rules*) A precise set of rules and a syntax that govern the accurate transfer of information. (2–*connection*) A procedure for connecting to a communications system to establish, carry out, and terminate communications.

Protocol Conversion The translation of the protocols of one system to those of another to enable different types of equipment, such as data terminals and computers, to communicate.

Provisioning The operations necessary to respond to service orders, trunk orders, and special-service circuit orders and to provide the logical and physical resources necessary to fill those orders.

Public Switched Telephone Network (PSTN) An unrestricted dialing telephone network available for public use. The network is an integrated system of transmission and switching facilities, signaling processors, and associated operations support systems shared by customers. PSTN is also called a public network, public switched network, or public telephone network.

Push Technology Is an old wireline telephony term now adapted to the Internet world. The term describes the "pushing" of information towards a network element or user. The process cannot be controlled by the receiving party.

Radio Radio is a telecommunications system that uses electromagnetic waves, transmitted through freespace. Information is transmitted because the electromagnetic waves are caused to vary in frequency or energy levels. The variations are interpreted as information.

Radio Common Carrier A common carrier licensed by the Federal Communications Commission (FCC) to provide mobile telephone services using radio systems.

Radio Determination Satellite Service A service that uses radio signals from satellites to determine the position and velocity of an object.

Radio Network Subsystem (RNS) A collection of a base stations and base station controllers. A base station controller manages multiple base stations in a GSM network. The base station controller is an additional layer of resource management.

Reconciliation Clearinghouse function for multiple carriers. Interconnected carriers terminate calls in one another's network. Under such circumstances, the carriers are entitled to some form of compensation; the compensation is determined though the independent call-record processing provided by the clearinghouse.

Regional Bell Operating Company (RBOC) One of the seven U.S. Telephone companies, also known as the "Baby Bells," that resulted from the break up of AT&T.

Ring Network A data network of circular topology in which each node is connected to its neighbor to form an unbroken ring. A ring network in which one of the nodes exercises central control often is called a loop.

Router *See* Routing Switcher.

Routing Switcher (1–*general*) An electronic device that connects a user-supplied signal (audio, video, and/or data) from any input to any user selected output. Inputs are called sources. Outputs are called destinations. (2–*network*) A device that forwards packets of a specific protocol type (such as IP) from one logical network to another. These logical networks can be the same type or different types. A router receives physical layer signals from a network, performs data-link and network-layer protocol processing, then sends the data to its destination.

Satellite (1–*general*) A body that revolves around another body of greater mass and has a motion primarily determined by the force of attraction of the more massive body. (2–*communications*) An orbiting space vehicle containing a set of transponders that receive signals from the ground and retransmit them to other ground-based receivers.

Satellite System A network of satellites and associated ground stations that transmit telephone, audio, video, and data signals between terrestrial points.

Search Engines Search engines are software defined products that are normally provided at no charge to the subscriber (Internet user). The search engine is an application that enables the user to find information from various websites. The user types in a keyword(s). The keyword is used by the search engine to find sites that are associated with a specific identifier.

Selective Call Acceptance (1) A CLASS feature that enables a customer to receive calls selectively from previously specified telephone numbers. All other calls are intercepted by a recorded denial announcement or routed to an alternate directory number, depending on the subscriber's selection when the service is activated. CLASS is a service mark of Bellcore. (2) A call screening service that allows a subscriber to receive incoming calls only from parties whose Calling Party Numbers (CPNs) are in an SCA screening list of specified CPNs.

Server (1–*telecommunications network*) The equipment, or a call-carrying path, that responds to a customer's attempt to use a network. (2–*LAN*) A processor that serves users on a local area network, for example, by storing and managing data files or by connecting users to an external network.

Service Access Code (SAC) The three-digit codes in the NPA (N 0/1 X) format that are used as the first three digits of a 10-digit address in a North American Numbering Plan dialing sequence. Although NPA codes are normally used for the purpose of identifying specific geographical areas, some of these NPA codes have been allocated to identifying generic services or to provide access capability, and these are known as SACs. The common trait, which is in contrast to an NPA code, is that SACs are nongeographic. Local Number Portability (LNP), if implemented, will obviate the geographic nature of the NPA code.

Service Objective A statement of the quality of service that is to be provided to a customer or group of customers.

Service Provider A generic name given to a company or organization that provides telecommunications service to customers (subscribers).

Short Message Service Point-to-Point (SMS-PP) Provides bearer service mechanisms for delivering a short message as a packet of data between two service users, known as Short Message Entities (SMEs). SMEs are SMS endpoints capable of composing or disposing of a short message. One or both of the service users may be a mobile station. The data packets are transferred transparently between two service users. The network or destination application may generate negative acknowledgments when it is unable to deliver the message as desired.

Signaling Link A communication path that carries common channel signaling messages between two adjacent signaling nodes.

Signaling Point (SP) In the SS7 protocol, a node in a signaling network that originates and receives signaling messages, transfers signaling messages from one signaling link to another, or both.

Signaling System Number 7 (SS7) An out-of-band common-channel signaling protocol standard designed to be used over a variety of digital telecommunication switching networks. It is optimized to provide a reliable means for information transfer for call control, remote network management, and maintenance.

Signaling Transfer Point (STP) In a common channel signaling network, a packet switch that uses the SS7 protocol to connect signaling links to network switching systems and other signaling transfer points.

Service Control Point (SCP) The database that contains the subscriber profiles. SCPs can also provide assistance in the routing of a call.

Service Switching Point (SSP) The switch (or routing element) in the SS7 network. The switch is a Class 5 central office in the wireline network (LEC). In the cellular or PCS world the SSP is the wireless switch or mobile switching center.

Smart Build A new term to describe what was always done prior to the Telecommunications Act of 1996; build where there are customers and build what they will pay money for. After the Telecommunications Act of 1996, the industry began a disastrous pattern of building to impress Wall Street; build big and fast and the customers will come. This new pattern of building telecommunications networks was not smart and not based on the marketplace.

Smart Building A new term to describe the old process of providing telecommunications services to building tenants, usually by the landlord. A smart building has its own telecommunications switch or router. The industry also use to call smart building, shared tenant services.

Soft Handoff Soft handoff is the reverse of the hard handoff scenario. Soft handoff is a "make-before-break" form of call handoff between radio channels, whereby the mobile handset temporarily communicates with both the serving cell site and the targeted cell site (one or more cell sites can be targeted) before being directed to release all but the final target cell site radio channel. Currently only CDMA supports soft handoff.

Space Operation Service A service concerned exclusively with the operation of spacecraft.

Space Research Services A research service where spacecraft are used for scientific or technical research.

Spectrum Spectrum is a continuous range of radio frequencies. It is used as a general reference in the wireless carrier community.

Star Network A data network with a radial topology in which a central control node is the point to which all other nodes join.

Supervisory Signals Signals used to indicate or control the status or operating states of circuits that establish a connection. A supervisory signal indicates that a particular state in a call has been reached and can signify the need for additional action.

Switched Circuits Circuits used in the support of establishing a call. These circuits are physically set up to connect telephones.

Switched Multimegabit Data Service (SMDS) SMDS is a 1.544-Mbps public data service.

Switching (1–*general*) The process of making and breaking (connecting and disconnecting) two or more electric circuits. (2–*telecommunications*) The process of connecting appropriate lines and trunks to form a communications path between two or more stations. Functions include transmission, reception, monitoring, routing, and testing.

Synchronous (1–*general*) In step or in phase, as applied to two or more devices; a system in which all events occur in a predetermined timed sequence. (2–*data communications*) An operation that occurs at intervals directly related to a clock period. The bus protocol in such data transactions is controlled by a master clock and is completed within a fixed clock period.

Synchronous Optical NETwork (SONET) A standard format for transporting a wide range of digital telecommunications services over optical fiber. SONET is characterized by standard line rates, optical interfaces, and signal formats.

T-Carrier Generic name given to describe any of the several analog transmission facilities used in the United States. T-carriers were first used in the Untied States during the early 1960s. The T-carrier first started off as a single twisted-pair of wires.

Tandem Switch A switch that supports a network topology where connectivity between locations is attained by linking several locations together through a single point. The tandem switch is very similar to the "traffic cop," directing traffic from several streets into other groups of streets.

Tariff Documents Documents filed by a wireline telephone company with a state Public Utility Commission (PUC) or the Federal Communications Commission. The tariff describes in detail the company's services and the pricing of said services. The tariff essentially explains and justifies the pricing of the service.

Taxpayer to Government (T2G) I am not being facetious. Today, taxpayers can file their income taxes over the Internet. Taxpayers can find a variety of information from the various government databases. Furthermore, we can file any number of requests for information (from government agency) over the Internet. I do not think the government will use the Internet as its primary way of conducting business with the taxpayer but the government can use it to enhance the flow of communication between itself and the people it serves.

Telecommunications The transmission, between or among points specified by the user, of information of the user's choosing (including voice, data, image, graphics, and video), without change in the form or content of the information.

Telecommunications Carrier Any provider of telecommunications services. A telecommunications carrier is treated as a common carrier under the Telecommunications Act only to the extent that it is engaged in providing telecommunications services.

Telecommunications Service The offering of telecommunications for a fee directly to the public, or to such classes of users as to be effectively available directly to the public, regardless of the facilities used.

Telegraphy A form of telecommunications concerned with the process of providing transmission and reproduction at a distance of text material or fixed images. The transmission of such information may be physical or over-the-air transmission facilities using some form of signaling protocol.

Television The transmission and reception of visual images via electromagnetic waves.

Terminal Equipment Computers, telephones, and other data or voice devices at the end of a telephone line.

Terminals Devices that typically provide the interface between the telecommunications system and the user. Terminals may be fixed (stationary) or mobile (portable).

Three-Way Calling (3WC) A service providing the subscriber the capability of adding a third party to an established two-party call, so that all three parties may communicate simultaneously.

Time Division Multiplexing (TDM) A method for sending two or more signals over a common transmission path by assigning the path sequentially to each signal, each assignment being for a discrete time interval. All channels of a time-division multiplex system use the same portion of the transmission link's frequency spectrum—but not at the same time. Each channel is sampled in a regular sequence by a multiplexer.

Toll Any message telecommunication charge for service provided beyond a local calling area.

Toll Center A very old term; i.e., predivestiture, used to describe a Class 4 central office. This is also known as the tandem switching center.

Toll Free A term used to refer to free calling numbers. A company would buy an 800 number that would enable users to call them without any calling charges. Today it also includes any calling number that users can call without incurring charges (e.g., 888).

Traffic Engineering Planning activity that determines the number and type of communications and signaling paths required between switching points and the call-processing capacity of the switching equipment.

Translation (1–*general*) The conversion of information from one form to another. (2–*switching system*) The conversion of all or part of a telephone address destination code to routing instructions or routing digits.

Transmission Control Protocol/Internet Protocol (TCP/IP) The protocol that manages the bundling of outgoing data into packets, manages the transmission of packets on a network, and checks the bundles for errors. This protocol is a networking protocol that supports communication across interconnected information networks; i.e., the Internet.

Transmission Plan Types of facilities used and transmission design requirements.

Trunk A single transmission path connecting two switching systems. Trunks can be shared by many users, but serve only one call at a time.

Trunk Group A number of trunks that can be used interchangeably between two switching systems.

Trunk Side Connection Transmission facilities that connect switches to each other.

Twisted Pair A pair of insulated copper wires used in transmission circuits to provide bidirectional communications. The wires are twisted about one another to minimize electrical coupling with other circuits. Paired cable is made up of a few to several thousand, twisted pairs.

Two-Wire Circuits A transmission circuit comprised of two wires that support the sending and reception of information.

Type 1 A connection that is a trunk-side connection to an end office. The end office uses a trunk-side signaling protocol in conjunction with a feature known as Trunk With Line Treatment (TWLT).

Type 1 with ISDN An ANSI-standard ISDN line between the LEC end office and the MSC. The ISDN connection should be capable of providing connectivity to the PSTN that will support ISDN PRI (Primary Rate Interface) and ISDN BRI (Basic Rate Interface). The ISDN connection is a variation of the Type 1 connection.

Type 2A A trunk-side connection to the LEC's access tandem. This connection allows the MSC to interface with the access tandem as if it were a LEC end office. This connection enables the wireless carrier's subscribers to obtain presubscription. The service provider will have access to any set of numbers within the LEC network.

Type 2B A similar interconnection type to the high usage trunk groups established by the LEC for its own internal routing purposes. In the case of wireless carrier interconnection, the Type 2B should be used in conjunction with the Type 2A. When a Type 2B is used, the first choice of routing is through a Type 2B with overflow through the Type 2A.

Type 2C A telephone system interconnection that is intended to support interconnection to a public safety agency via a LEC E911 tandem or local tandem. This connection enables a wireless carrier to route calls through the PSTN to the Public Safety Answering Point (PSAP). This connection supports a limited capability to transport location coordinate information to the PSAP via the LEC.

Type 2D A telephone system interconnection that is intended to support interconnection to the LEC's operator service position. This connection enables the LEC to obtain ANI (Automatic Number Identification) information about the calling wireless subscriber in order to create a billing record.

Type S A telephone system interconnection that only carries control messages. The Type S is a SS7 signaling link from the wireless carrier to the LEC. The Type S supports call setup via the ISUP (ISDN User Part) portion of the SS7 signaling protocol and TCAP querying. The Type S is used in conjunction with the Type 2A, 2B, and 2D.

Universal Resource Locator (URL) Used in the Internet. URLs refer to the Internet addresses used on the World Wide Web. The URL is a string expression that can represent any resource on the Internet.

Uplink The earth-to-satellite microwave link and related components such as earth station transmitting equipment.

The satellite contains an uplink receiver. Various uplink components in the earth station are involved with the processing and transmission of the signal to the satellite.

Validation Validation is often confused with authentication. Where authentication essentially certifies the user as either "real" or "fake" and also as either "good" or "bad," validation certifies the "permission" to complete the call. A user calls another party using a mobile handset. The carrier certifies that the handset is the real one and is not a clone being used by a criminal. Once the handset has been given the "thumbs up" the carrier then checks to see if the call is allowed under the user's billing plan. This next step is validation, being given the final "green light" to complete the call.

Vector Quantizing Code (VQC) The VQC methodology is based on PCM. However, the difference is rather than transmitting individual samples, VQC systems transmit information regarding a series of samples. A vector is defined as a string of bits (0s and 1s) that form a pattern. The vector that results is compared to vectors stored in the transmission system's database. The closest match is found and the code for that stored vector is sent to the receiving end. In other words one is matching patterns stored in a database.

Very High Rate Digital Subscriber Line (VDSL) A high-speed transmission technology intended to be used in the local loop. VDSL technology supports fiber optics to a neighborhood, while the last "mile" to the specific home still uses unshielded twisted pairs of wires.

Video An electrical signal that carries TV picture information.

Video on Demand (VOD) A service that telephone companies were seeking to bring to their subscribers. VOD would enable a subscriber to request any video they wished to see, at any given time.

Virtual Circuits A telecommunications link that appears to the user to be a dedicated point to point circuit.

Visitor Location Register (VLR) The part of a wireless network (typically cellular or PCS) that holds the subscription and other information about visiting subscribers who are authorized to use the wireless network.

Voice Mail (1) A computer-based system for the delivery, storage, forwarding, and retrieval of voice messages, especially those carried by telephone networks. (2) An application that provides the subscriber with voice mail services, which include not only the basic voice recording functions but also time-of-day recording, time-of-day announcements, menu driven voice-recording functions, and time-of-day routing.

Wave Division Multiplexing (WDM) WDM is a fiber optical transmission systems that uses more than one light beam, simultaneously. WDM is a combined frequency division multiplexing (FDM) and time division multiplexing (TDM) schema.

Wideband The passing or processing of a wide range of frequencies. The meaning varies with the context. In an audio system, wideband may mean a band up to 20 kHz wide; in a TV system, the term may refer to a band many megahertz wide.

Wink A telephone line signal that is a single supervisory pulse usually transmitted as an off-hook signal followed by an on-hook signal where the off-hook signal is of a very short specified duration compared to the on-hook signal.

Wireless Local Loop (WLL) The process of providing local telephone service via radio transmission.

xDSL A set of large-scale high-bandwidth data technologies that can use standard twisted-pair copper wire to deliver high-speed digital services (up to 52 Mbps) to the home or business.

X.25 The X.25 protocol is a Data Link layer protocol; specifically X.25 uses the LAP-B portion of this layer.

Zone Zone is a term is used to describe a customer serving area. The term is tied to billing. Billing zones are geographic areas of customers.

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APPENDIX B

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Note: boldface numbers indicate illustrations; italic *t* indicates a table.

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P. J. Louis is a telecommunications industry expert, currently consulting in the financial arena. Louis had been Vice President of Marketing and Project Management at TruPosition, Inc., a leader in wireless location systems. A former Director of Network Technology at NextWave Wireless, he is an electrical engineer with a master's in technology management who understands both business and technical sides of communications. The author of *Telecommunications Internetworking and the M-Commerce Crash Course*, he is also a former senior managing engineer at Bell Communications Research, Inc. and former engineering director (and chief of staff for engineering) for NYNEX. Louis had been responsible for planning and rolling out the Equal Access switching configurations, first out-of-band signaling networks (SS7 networks), the telecom industry's early intelligent networks, the first generation of digital switches, first and second generation wireless network interconnections (both Bellcore and TIA versions), and the wireless industry standard called IS-41 (from Revision 0 through C). For several years, Louis also served as a standards committee chairman in the ANSI accredited Telecommunications Industry Association (TIA). Louis has been fortunate to have been a part of many of the telecom industry's technology and business evolutionary stages.

Louis was a member of the editorial advisory board for *Cellular Marketing Magazine*. Louis has been a featured writer for *Cellular Networking Perspectives*; an industry newsletter. Louis is a senior member of the Institute of Electrical and Electronics Engineers (IEEE). Louis was a former officer of the IEEE's Communications Society–NY Section. Louis is a member of the Radio Club of America. Louis is a member of the Association of Old Crows. He earned his B.S. in electrical engineering at Columbia University and his M.S. in technology management from Polytechnic University of New York. Mr. Louis is often a featured speaker at gatherings of telecom professionals.