Chapter

1

Introduction

Since its inception, the mobile wireless industry has undergone tremendous changes and has seen a plethora of technologies introduced. While the technologies utilized may seem diverse, they all are based on similar concepts and have similar objectives: the delivery of voice and some data applications. By understanding the similarities and differences between available wireless systems, it is possible to determine how to improve their performance while offering unique services.

In the next few chapters we discuss numerous aspects pertaining to the design, deployment, and operation of mobile wireless systems. This chapter briefly covers some of the key concepts and terminology of mobile wireless communication commonly referred to as cellular communications. The term *cellular communications* is often interchanged with the terms *personal communication services (PCS),* and *third-generation (3G) services,* all of which are interrelated.

The wireless industry continues striving to augment or even replace the wired local loop. This effort has fostered the development of numerous radio technologies that operate over a vast range of spectrums from 400 megahertz (MHz) to 40 gigahertz (GHz). Initially wireless access involved delivering analog or digitized voice services utilizing a host of modulation techniques. The primary focus was on the deployment of radio base stations and then on the development of adjunct services to retain customers and enhance revenues. But as the Internet and other bandwidth-hungry services and products have become more prolific in society, the delivery of data taking precedence over the delivery of voice services is what is envisioned.

With the proliferation of the Internet protocol (IP) and its permeation into all aspects of life, both business and personal, the need to support additional services has become the driving force for all wired and wireless technologies. Society is being revolutionized through better access to information for the purposes of making business as well as purchasing decisions. The available information is so vast that traditional concepts of time and location no longer apply (that is, information is accessible anytime, anyplace). But the revolution is expected to take several years to fully unfold due to the current bandwidth bottleneck that exists at the "last mile" of any system, both wired and wireless. Numerous technology platforms that provide the needed bandwidth to facilitate the information revolution are currently being deployed or are being considered for deployment. The difficulty in the technology platform race is to determine which transport medium will meet both the current demand mode and any future demand models.

1.1 Communication History

Data communication began with Samuel Morse, who in 1844 invented and pioneered the telegraph, which used Morse code (consisting of interweaving dots and dashes) as its method for delivering communication over vast distances. This coding method was so good that it is still used extensively throughout the world today. Wireless data communication became possible thanks to the efforts of Guglielmo Marconi, who is credited with inventing radio.

A very condensed time line of major milestones for the telecommunication industry is provided here. There are numerous other milestones of equal importance for communications, but this list represents shifts in thinking.

1844 Samuel Morse invents the telegraph.
1876 Alexander Bell invents the telephone.
1901 Guglielmo Marconi sends Morse code using a radio.
1931 First U.S. television transmission takes place.
1946 AT&T offers mobile phone service.
1953 First microwave network installed.
1956 Transatlantic cable constructed.
1977 Bell Labs transmits TV signals on optical fibers.
1983 Cellular communication fosters another communications revolution.

Wireless systems have not been in existence long. The first systems were both two-way and broadcast. Radio communication at its onset focused primarily on voice communications, but with the advent of television it was used to deliver broadband video coupled with data for instructing the television on how to display the picture. Microwave communications fostered in the high-speed delivery of data where speeds of 155 megabits per second (Mbit/s) are now common.

The wired systems have also taken a major leap from just offering voice. Data applications initially involved use of a modem that operated at 300 baud, which then progressed to 1200 baud. Speeds now exceed 1 gigabit per second (Gbit/s) with higher speeds being reached every year as the need for more throughput increases.

Part of the need for more throughput was the invention of the fax machine and the proliferation of the computer and its numerous technological advances. The Internet has created the need for increased bandwidth so that a host of services, some still only being dreamed of, can be delivered to subscribers.

The transport platforms for voice and data are becoming similar and require not only bandwidth but design and management skills. The communications future at this time appears to be heading toward using IP as the primary edge or end-user protocol with other supporting transport protocols like asynchronous transfer mode (ATM) being used to deliver the information between similar and dissimilar networks.

1.2 Cellular

Cellular communication is one of the most prolific voice communication platforms that has been deployed within the last two decades. Cellular systems have always been able to transport data, and many advancements in different modulation formats allow for the delivery of narrowband data. However, cellular systems are unable to provide broadband data services because of bandwidth limitations. Typical data rates experienced by cellular applications are 9 kilobits per second (kbit/s).

Overall, cellular communication is the form of wireless communication that allows for

- Frequency reuse
- Mobility of the subscriber
- Handoffs

The cellular concept is employed in many different forms. Typically, when someone refers to cellular communication, the reference is to advanced mobile phone system (AMPS) or total-access communications system (TACS) technology. AMPS operates in the 800-MHz band: 821 to 849 MHz for the base station receive and 869 to 894 MHz for the base station transmit. For TACS the frequency range is 890 to 915 MHz for the base station receive and 935 to 960 MHz for the base station transmit.

Many other technologies also fall within the guise of cellular communication; these include both the domestic U.S. and the international PCS bands. In addition the same concept is applied to several technology platforms that are currently used in the specialized mobile radio (SMR) band. [IS-136 and integrated dispatch enhanced network (iDEN)]. However, cellular communication really refers to the AMPS and TACS bands but is sometimes interchanged with the PCS and SMR bands because of the similarities.

The concept of cellular radio was initially developed by AT&T at their Bell Laboratories to provide additional radio capacity for a geographic customer service area. The initial mobile systems from which cellular evolved were called mobile telephone systems (MTS). Later improvements to these systems occurred, and the systems were then referred to as improved mobile telephone systems (IMTS). One of the main problems with these systems was that a mobile call could not be transferred (handed off) from one radio station to another without loss of the signal. This problem was resolved by reusing the allocated frequencies of the system. With the handoff problem solved, the market was able to offer higher radio traffic capacity, which allowed for more users, in a geographic service area than with the MTS or IMTS. Cellular radio was thus a logical progression in the quest to provide additional radio capacity for a geographic area.

The cellular systems in the United States are broken into metropolitan statistical areas (MSAs) and rural statistical areas (RSAs). Each MSA and RSA has two different cellular operators that offer service. The two cellular operators are referred to as A-band and B-band systems. The *A band* is the nonwireline system, and the *B band* is the wireline system for the MSA or RSA. A brief configuration for a cellular system is shown in Fig. 1.1.

There are numerous types of cellular systems used in the United States and elsewhere. Here is a brief listing of some of the more common ones. All are similar in network layout in that they have base stations connected to a mobile switching center (MSC) that in turn connects to the public switched telephone network (PSTN) or postal, telegraph, and telephone (PTT) system.

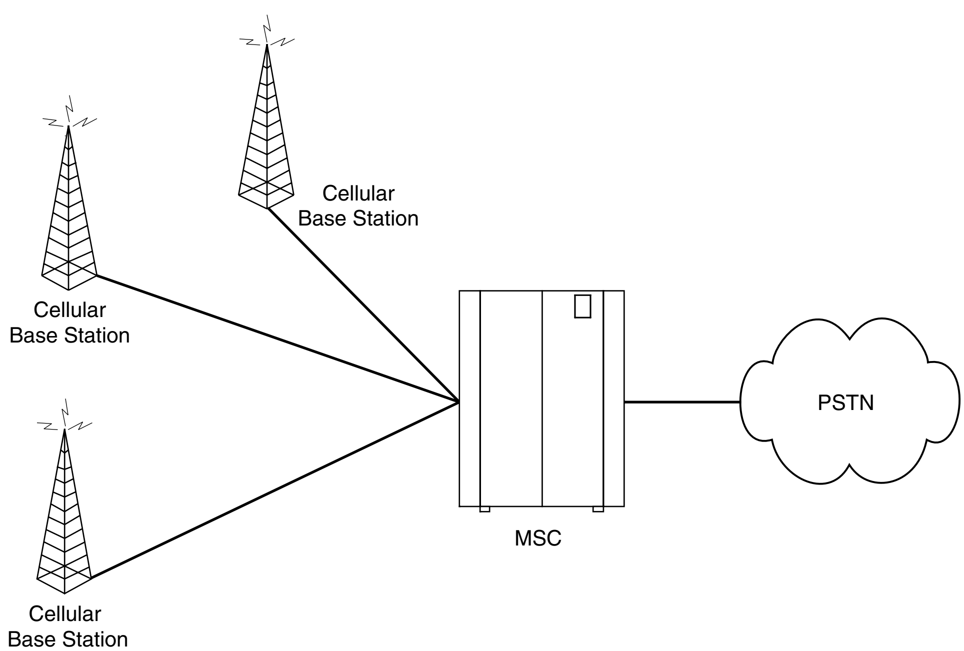

Figure 1.1 Generic cellular system.

1. *Advanced mobile phone system (AMPS).* The cellular standard developed for use in North America. This type of system operates in the 800-MHz frequency band and has also been deployed in South America, Asia, and Russia.
2. *Code-division multiple access (CDMA).* An alternative digital cellular standard developed in the United States. It utilizes the IS-95 standard and is implemented as the next generation for cellular systems. The CDMA system coexists with the current analog system.
3. *Digital AMPS (D-AMPS).* The digital standard for cellular systems developed for use in the United States, also called *North American digital cellular (NADC).* When the existing analog systems needed to be expanded because they were growing at a rapid pace, instead of the creation of a new standard, the AMPS standard was developed into the D-AMPS digital standard. The D-AMPS is designed to coexist with current cellular systems and relies on both the IS-54 and the IS-136 standards.
4. *Global system for mobile communications (GSM).* The European standard for digital cellular systems operating in the 900-MHz band. This technology was developed out of the need for increased service capacity due to the analog system's limited growth. This technology offers international roaming, high speech quality, increased security, and the ability to develop advanced systems features. It was completed by a consortium of 80 pan-European countries working together to provide integrated cellular systems across different borders and cultures.
5. *Nordic mobile telephone (NMT).* The cellular standard developed by the Nordic countries of Sweden, Denmark, Finland, and Norway in 1981. This type of system was designed to operate in the 450- (NMT 450) and 900-MHz (NMT 900) frequency bands. NMT systems have also been deployed throughout Europe, Asia, and Australia.
6. *Total-access communications system (TACS).* A cellular standard derived from the AMPS technology. TACS operates in both the 800- and 900-MHz bands. The first system of this kind was implemented in England. Later these systems were installed in Europe, China, Hong Kong, Singapore, and the Middle East. A variation of this standard (*JTACS*) was implemented in Japan.
7. *Integrated dispatch enhanced network (iDEN).* The name for an alternative form of cellular communication which operates in the SMR band just adjacent to the cellular frequency band. iDEN is a blend of wireless interconnect and dispatch services which makes it very unique compared to existing cellular and PCS systems. iDEN utilizes a digital radio format called quadrature amplitude modulation (QAM) and is a derivative of GSM for the rest of the system with the exception of the radio link.

1.3 PCS

Personal communication services (PCS) is the next generation of wireless communications. It is a general name given to wireless systems that have recently been developed out of the need for more capacity and design flexibility than that provided by the initial cellular systems. The similarities between PCS and cellular lie in the mobility of the user of the service. The differences between PCS and cellular fall into the applications and spectrum available for PCS operators to provide to subscribers.

PCS, like its cellular cousin, is another narrowband service which offers many enhanced data services in conjunction with voice services. It was heralded in as providing many data services which would enable people to use one communication device for all their foreseeable needs. However, because of the bandwidth limitations associated with the PCS systems deployed, the data throughput remained at 9.6 kbit/s.

Wideband PCS has many promises for offering high-speed data but has not yet been deployed because there are particular problems that must be overcome. The obvious issue is coexistence with the current PCS system. Coupled with the coexistence problem is the need for more base stations due to reduced sensitivity caused by increased bandwidth. The third major problem that needs to be overcome is the offering of subscriber units that can act as dual band units in a vastly diverse PCS marketplace.

Figure 1.1, while labeled as a cellular system, has the same format and layout as a PCS system. The chief difference is that the frequency of operation is higher for PCS and therefore more base stations are required in order to cover the same geographic area.

The diverse PCS systems that an operator can possibly utilize are listed here. It is important to note that in several markets the same operator can and has deployed several types of PCS systems in order to capture market share.

1. *DCS1800.* A digital standard based upon the GSM technology with the exception that this type of system operates at a higher frequency range, 1800 MHz. This technology is intended for use in personal communication network (PCN) systems. Systems of this type have been installed in Germany and England. (DCS stands for digital cellular system.)
2. *PCS1900.* A GSM system which is the same as DCS1800 except that it operates in the PCS frequency band for the United States, 1900 MHz.
3. *Personal digital cellular (PDC).* A digital cellular standard developed in Japan. PDC-type systems were designed to operate in the 800-MHz and 1.5-GHz bands.
4. *IS-661.* The technology platform that is being promoted by Omnipoint. It is a spread-spectrum technology that relies on time-division duplexing (TDD).
5. *IS-136.* The PCS standard that relies on the NADC system except that it operates in the 1900-MHz band.

6. *CDMA*. Another popular PCS platform utilizing the same standard as that for CDMA in cellular except that it too operates in the 1900-MHz band.

In the United States, PCS operators obtained their spectrum through an action process set up by the Federal Communications Commission (FCC). The PCS band was broken into A, B, C, D, E, and F blocks. The A, B, and C blocks involved a total of 30 MHz, while the D, E, and F blocks are allocated 10 MHz.

The spectrum allocations for both cellular and PCS in the United States are shown in Figs. 1.2 and 1.3. It should be noted that the geographic boundaries for PCS licenses are different than those imposed for cellular operators in the United States. Specifically PCS license boundaries are defined as metropolitan trading areas (MTAs) and basic trading areas (BTAs). The MTA has several BTAs within its geographic region. There are a total of 93 MTAs and 487 BTAs defined in the United States. Therefore, there are a total of 186 PCS MTA licenses, each with a total of 30 MHz of spectrum to utilize; this is in addition to the 1948 BTA licenses awarded in the United States. Regarding the PCS licenses, the A, B, and C bands will have 30 MHz of spectrum each while the D, E, and F blocks will each have only 10 MHz available. All the frequency allocations are duplexed.

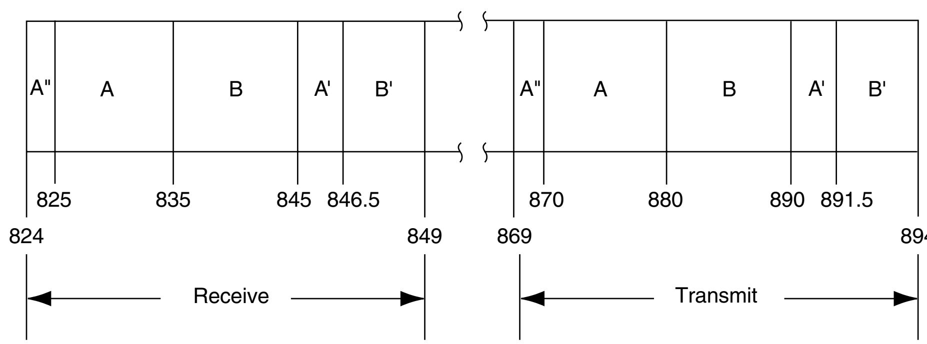

Figure 1.2 U.S. cellular spectrum chart (all frequencies in MHz).

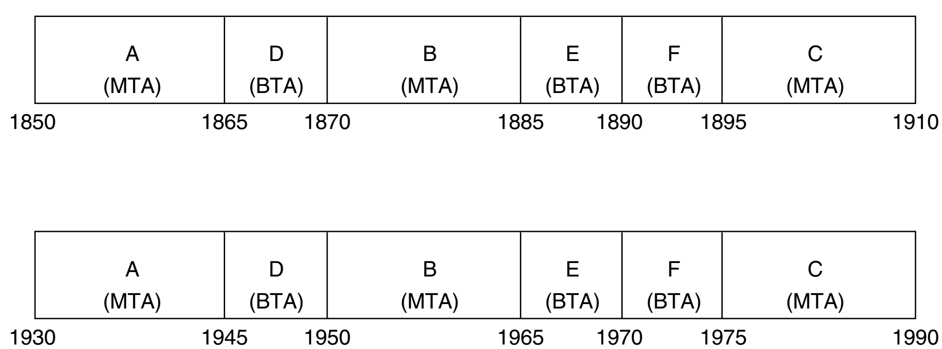

Figure 1.3 PCS spectrum allocation (all frequencies in MHz).

1.4 WLL

The wireless local loop (WLL) system utilizes many similar, if not the same, platforms as used in the cellular and PCS systems and is primarily focused on voice services. The WLL system, however, is different from the cellular or PCS systems in its application, which is fixed. Being a fixed service it is often referred to as a local multipoint distribution system (LMDS) or a fixed wireless point-to-multipoint (FWPMP) system. In fact, WLL in many cases is the same as LMDS or FWPMP in its deployment and application. WLL is most applicable in areas where local phone service is not available or cost effective. Primarily WLL is a system that connects a subscriber to the local telephone company (PTSN or PTT system) using a radio link as its transport medium instead of copper wires.

There is no specific band that WLL systems occupy or are deployed in. The systems can either operate in a dedicated, protected spectrum or in an unlicensed spectrum. Some of the services that fall within the definition of WLL include cordless phone systems and fixed cellular systems, as well as a variety of proprietary systems.

Given the wide choice of system types and the spectrum considerations, the choice of which combination of system types to use is directly dependent upon the application and services desired. Some of the additional considerations for choosing the right technology platform involve the determination of the geographic area needed to be covered, the subscriber density, the usage volume and patterns expected from the subscribers, and the desired speed of deployment.

Since no one radio protocol and service can do everything, the choice of which system to deploy will be driven by the desired market and applications required to solve a particular set of issues. Some of the more common types of WLL systems involve cellular, PCS, cordless telephone (CT-2), and digital European cordless telecommunication (DECT).

WLL has different implications when deployed in a developed country than when deployed in an emerging country. For a developed country WLL allows for use of a cordless phone as an extension of the house phone or private branch exchange (PBX), which is an added convenience. However, in an emerging country, which has areas without any access to a communication service, the use of WLL can create profound changes because it is quicker, easier, and less expensive to install than a regular landline system.

Figure 1.4 represents a typical WLL system. The WLL system has various nodes that are connected back to a main concentration point. The method for connecting the nodes to the concentration point can be by radio, wire, cable, or a combination of all three. Table 1.1 is a general representation of different technology platforms that can be used depending on the application involved. This generalization illustrates that there is no single platform or application to use when deploying WLL systems.

1.5 LMDS

The local multipoint distribution system (LMDS) is a unique wireless access system whose purpose is to provide broadband access to multiple subscribers

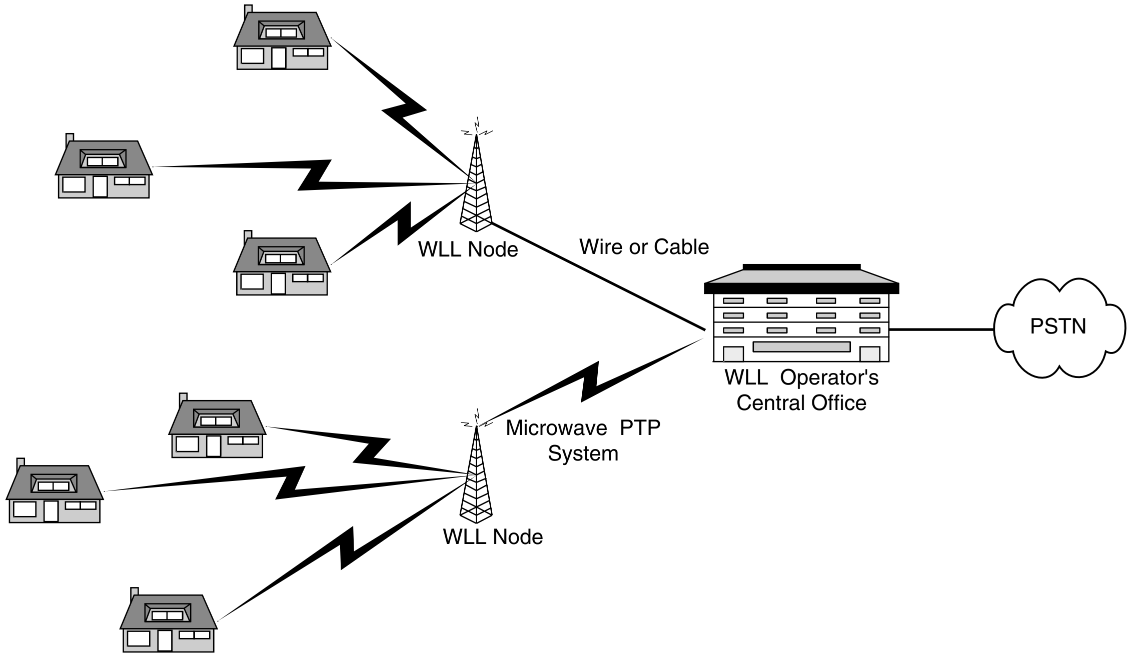

Figure 1.4 Wireless local loop (WLL).

TABLE 1.1 WLL Technology

Geographic area	WLL technology
Urban	Digital cellular
	DECT
	CT-2
	LMDS
	Proprietary radio system
Suburban	Digital cellular
	DECT
	LMDS
	Proprietary radio system
Rural	Analog cellular
	Digital cellular
	Proprietary radio system

in the same geographic area. Presently the majority of the systems that have deployed or started to deploy LMDSs are experiencing financial stress. However, there are numerous advantages to an LMDS that can help augment a mobile wireless system by providing a high bandwidth to selected areas or campus environments coupled with 802.11 (wireless LAN protocol). Additionally LMDSs can be used as an effective backhaul method for data traffic.

The LMDS utilizes microwave radio as the fundamental transport medium and is not really a new technology. It is an adaptation of existing technology for a new service implementation that allows multiple users to access the same radio spectrum. The LMDS is a wireless system that employs cellular-like design and reuse with the exception that there is no handoff. It can be argued that LMDS is in fact another variant to the WLL portfolio described previously and referenced as proprietary radio systems.

LMDS consists of two key elements, the physical transport layer and the service layer. The physical transport layer involves both radio and packet- and circuit-switching platforms. The radio platform consists of a series of base stations providing the radio communication link between the customers and the main concentration point, usually the central office of the LMDS operator. Figure 1.5 is a high-level system diagram of an LMDS. The system as shown has a similar layout as that for a cellular or PCS mobile system with the obvious difference being that the subscribers are fixed and, of course, operate at a different frequency.

The system diagram depicts multiple subscribers (customers) surrounding an LMDS hub or base station. The base station is normally configured as a sectorized site for frequency reuse purposes, and there are multiple subscribers

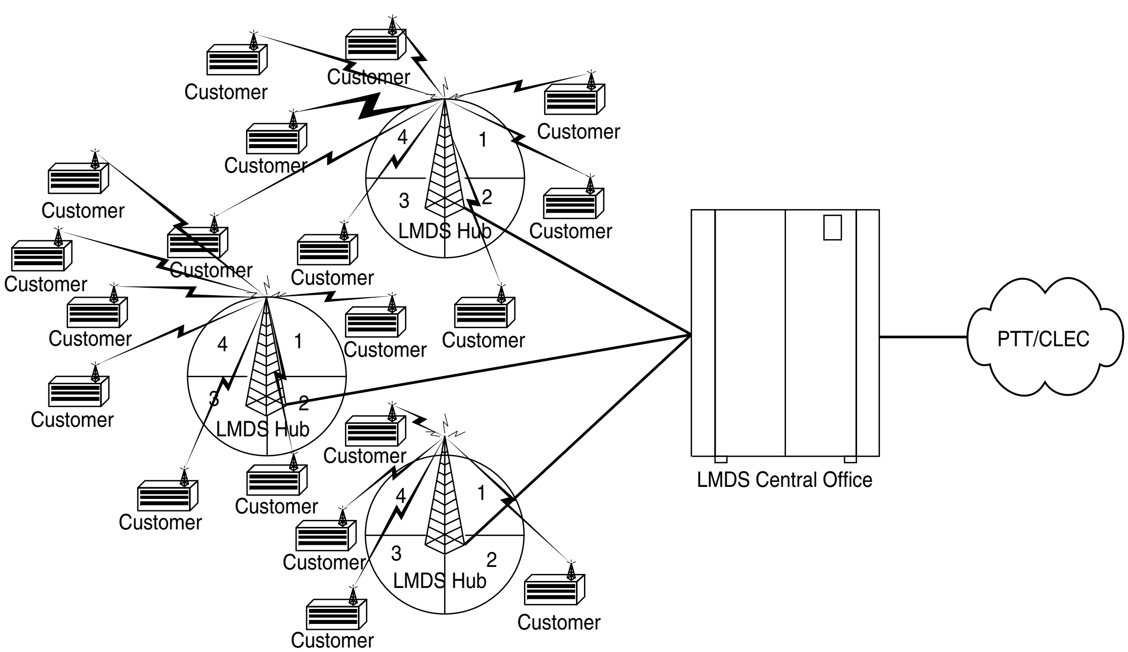

Figure 1.5 Generic LMDS system.

assigned to any sector. The amount of channels and the overall frequency plan for the system are driven by the spectrum available in any given market and the amount of capacity required in any geographic zone.

The LMDS is a point-to-multipoint system where multiple subscribers can access the same radio platform utilizing both a multiplexing method as well as queuing. Specifically a single radio channel may have 12-Mbit/s total throughput, but you might be able to offer 24 Mbit/s or greater for the same channel by allocating it to the entire sector and not to specific customers through overbooking. There, of course, are quality-of-service (QOS) issues and specific service delivery requirements with any commercial system. However, the concept is that an LMDS utilizing point-to-multipoint technology can provide vastly greater bandwidth and services to a larger population than a point-to-point system utilizing the same spectrum can.

Unlike mobile systems an LMDS has several key differences. The first is that ubiquitous coverage is not required; this is a key advantage. The LMDS if deployed properly can have the operator only provide service where the customers are actually located thereby maximizing the capital infrastructure effectiveness and minimizing operating expenses.

The other issue with LMDS relates to the fixed subscriber base that is potentially there. A primary concept of LMDS delivery is to provide the service not to one customer in a sector but to multiple customers. The concept is further carried to each building where the service is deployed. Specifically, LMDS is best positioned when there are multiple customers that utilize the same radio equipment, thereby maximizing the capital infrastructure installed at that location.

A brief example of a building having multiple customers is shown in Fig. 1.6. The simple concept of having multiple customers per geographic location will minimize the cost of acquisition for any customer and at the same time reduce operating and capital costs. It is important to note that initially the building where the equipment is to be deployed should be evaluated in order to properly establish its bandwidth potential. In this example, it is assumed that access to the wiring closet is achieved for distribution of the services offered. Also, Fig. 1.6 implies that there is LOS (line of sight, that is, no obstructions) with the hub site in order to ensure that the link is of sufficient quality for stable and reliable communication.

LMDS can be a very cost effective alternative for a competitive local exchange carrier (CLEC). With LMDS a CLEC can deploy a wireless system without having to experience the heavy capital requirements of laying down cable or copper to reach customers. The cost effectiveness is born out of the ability to focus the capital infrastructure where the customers are and at the same time being able to deploy the system in an extremely short period of time.

Some of the services that LMDS can offer customers are listed here. Note that the service offered cannot have a bandwidth requirement greater than what the radio transport layer can support.

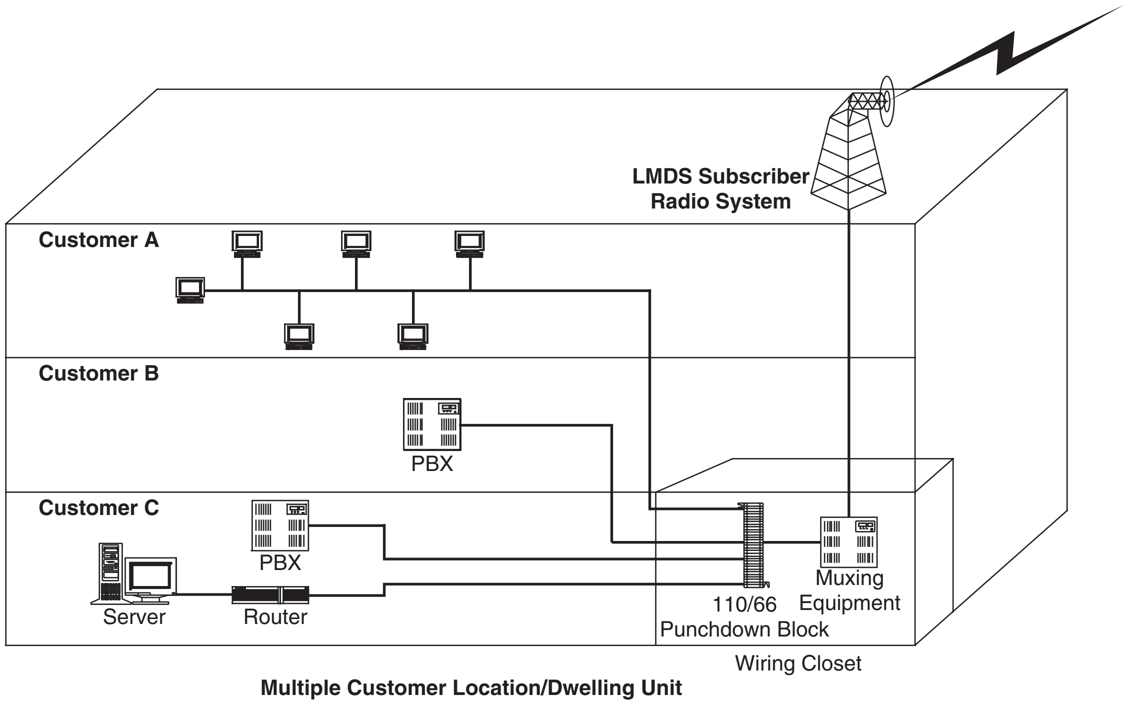

Figure 1.6 Host location.

Applications

- LAN/wide area network (WAN) [virtual private network (VPN)]
- Lease line (T1/E1) replacement (clear and channelized)
- Fraction T1/E1 (clear and channelized)
- Frame relay
- Voice telephony [plain old telephone service (POTS) and enhanced services]
- Videoconferencing
- Internet connectivity
- Web services [e-mail, hosting, virtual Internet service provider (ISP), etc.]
- E-commerce
- Voice over IP (VoIP)
- Fax over IP (FaxIP)
- Long-distance and international telephony
- Integrated systems digital network (ISDN) [basic rate interference (BRI) and primary rate interference (PRI)]

The host of services and perturbations to those just listed make an impressive portfolio. Of course, the necessary platforms and connectivity for the network need to be in place in order to ensure that these services can and will be offered and effectively delivered. It is interesting though that with an LMDS, as with any network, there are on-net and off-net traffic considerations. Ideally the traffic should be all on-net, but when the system initially goes on-line, most, if not all, the traffic goes off-net and the PTT system or another CLEC will need to be used almost exclusively to facilitate the delivery of the service.

As with all wireless systems, there are multiple LMDS from which an operator can choose to deploy. Some of the system architectures to pick from are frequency-division duplexing (FDD), TDD, time-division multiplexing (TDM)/ATM, ATM, FDD/TDM. Coupled with the transport method, the choice of modulation scheme as well as frequency planning options must all be weighed. Additionally another often overlooked aspect is the method for actually delivering service to a customer and the physical and electrical demarcation location and method.

1.6 MMDS, MDS, ITFS

Multichannel, multipoint distribution systems (MMDSs); instructional television fixed service (ITFS); and multipoint distribution service (MDS) are all sister bands to LMDS. The combination of MMDS, ITFS, and MDS bands make up what is referred to as *wireless cable*.

A total of 33 channels, each 6-MHz wide, make up the MMDS, MDS, and ITFS bands collectively. The bands, while currently being referenced together, were all developed for different reasons. However, the bands were originally broadcast related in that they were one-way oriented. The exception was the ITFS channels, which allocate a part of the band for upstream communication.

The MMDS, MDS, ITFS band has numerous subscribers utilizing its service. However, there has been increased activity in redefining the services the band can and will offer subscribers. The primary focus of the band is toward high-speed Internet traffic as compared to video services in conjunction with data. To make this happen the band has been allocated for two-way communication. But the channels are not paired as is done commonly in other bands. The two technology types now competing for use in this band are the FDD and TDD systems.

The technologies being deployed for the MMDS, MDS, and ITFS band are similar to that for the LMDS in that they involve a sectorized cell site which has multiple subscriber terminals associated with each channel in every sector. One of the key advantages the MMDS, MDS, and ITFS band has is the frequency this band operates within. The bands for operation are 2.15 to 2.162 GHz and 2.5 to 2.686 GHz, which do not require strict adherence to line of sight (LOS) for communication reliability as well as the elimination of rain fade considerations in the link budget.

The chief disadvantage with this band is the coordination an operator must achieve in order to utilize a particular frequency in a geographic area. The coordination is exceptionally tricky due to the present existence of MMDS, MDS, and ITFS operators that primarily utilize video as their service offering. The issue arises from both upstream and downstream frequency coordination since existing operators designed their systems based on a broadcast system basis.

1.7 Cable Systems

The proliferation of cable modems, primarily in the United States, has brought broadband service to many end users who were previously relying on dial-up IP. Cable operators have a unique advantage, as do PTT services, for delivering broadband services to the residential market because they already have a presence in many residential homes.

The common issue facing all broadband providers is the quality of their underlying transport layer. The quality of the cable plant itself dictates the delivery of services that can effectively be offered. The issues with cable plant quality are primarily driven by the number of drops (the wire or cable that connects to a house or building, as well as the wire or cable splits within the house or building) that are on any cable leg, which directly impacts the ingress noise problem that limits the ability for the cable plant to provide high-speed two-way communication. Since most of the information flow is from the head end to the subscriber, the system does not have to support symmetrical bandwidth requirements.

A hybrid fiber/coax (HFC) network is shown in Fig. 1.7, with the enhancement of providing two-way communication for both voice and data, besides the video service offering. The primary access method is physical media where the connection made to the subscriber at the end of the line is via coaxial cable. For increased distance and performance enhancements fiber-optic cables are often part of the cable network's topology.

Figure 1.8 is an example of a cable operator utilizing wireless access as the last leg in the access system. The wireless device listed can be a base station or a small remote antenna driver/remote antenna signal processor (RAD/RASP) unit installed on the coaxial cable itself. The figure depicts the potential for a cable operator and a wireless operator to utilize each other's infrastructure to deliver services. It should be noted that PCS is listed in Fig. 1.8 not only for mobility telephony but potentially also for better allocation for the PCS C band auctioned in the United States for delivering last-mile, high-bandwidth services.

1.8 WAP

The wireless application protocol (WAP) is one of the many broadband protocols being implemented into the wireless arena for the purpose of increasing mobility by enabling mobile users the ability to surf the Internet. WAP is being

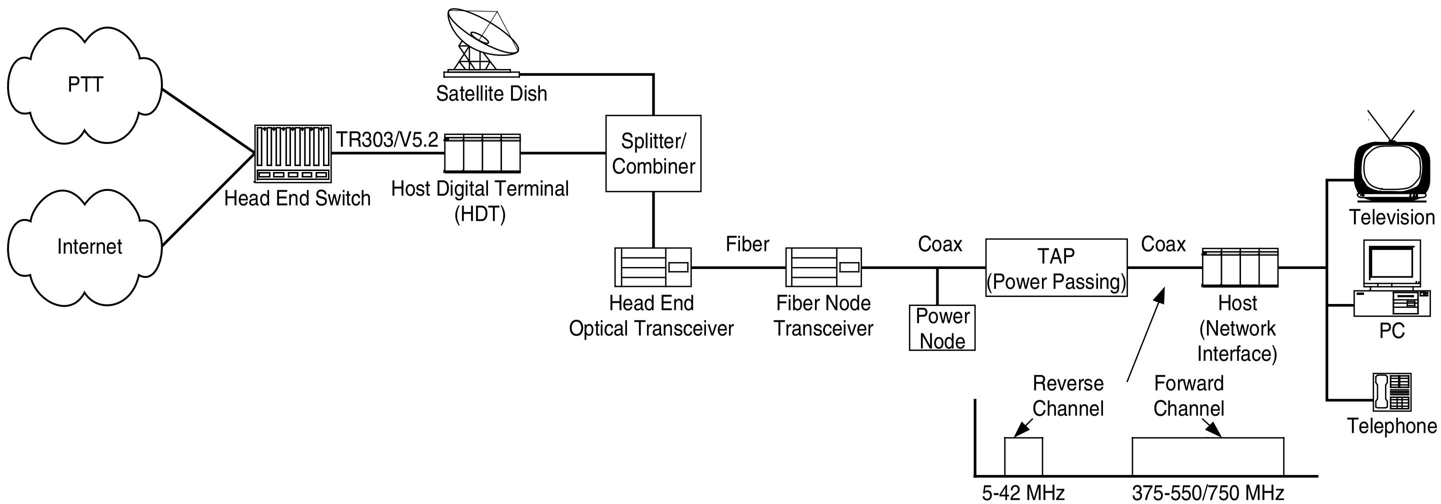

Figure 1.7 HFC.

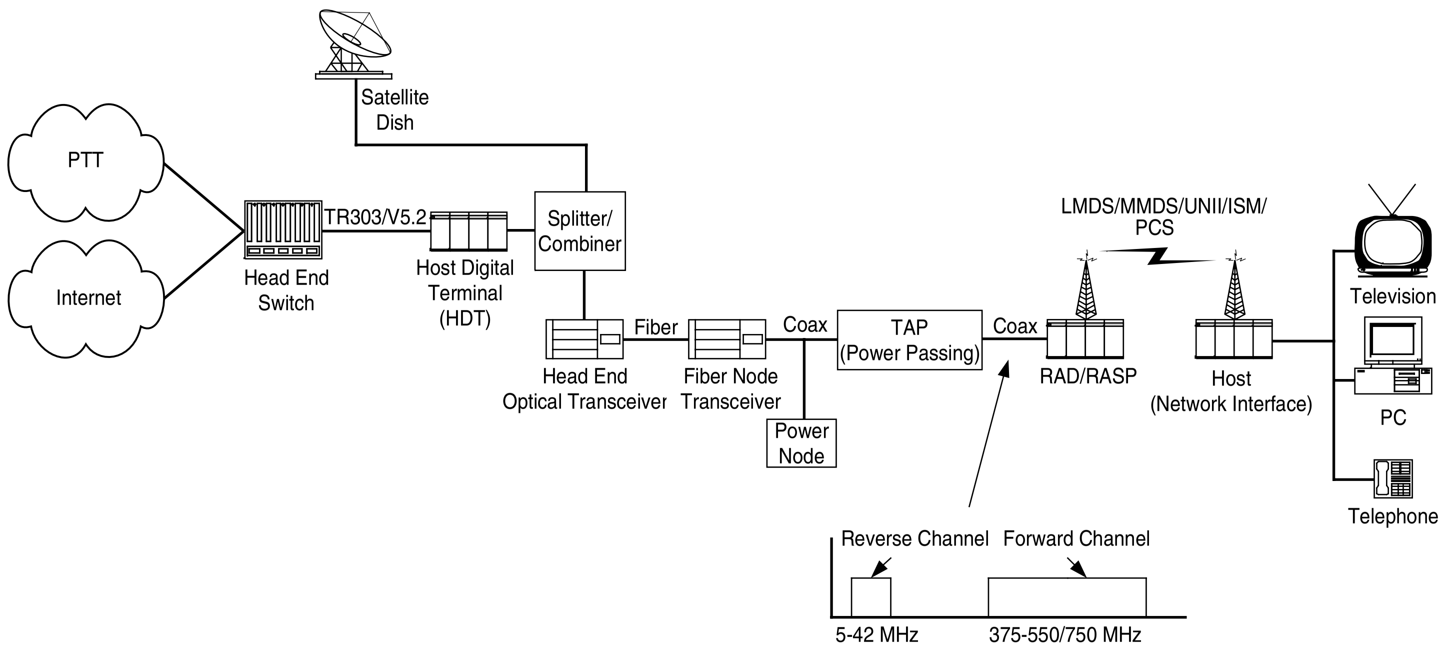

Figure 1.8 RAD/RASP.

implemented by numerous mobile equipment vendors since it is meant to provide a universal open standard for wireless phones (i.e., cellular/GSM and PCS) for the purpose of delivering Internet content and other value-added services. Besides various mobile phones, WAP is also designed to be utilized by personal digital assistants (PDAs).

WAP will enable mobile users to surf the Internet in a limited fashion; that is, they can send and receive e-mails and surf the net in a text-only format (without graphics). For WAP to be utilized by a mobile subscriber the cellular or PCS wireless operator needs to implement WAP in its system as well as ensuring that the subscriber units (i.e., the phones) are capable of utilizing the protocol. WAP is meant to be used by the following cellular/PCS system types:

- GSM-900, GASM-1800, GSM-1900
- CDMA IS-95
- TDMA IS-136
- 3G systems: IMT-2000, universal mobile telecommunications system (UMTS), wideband-CDMA (W-CDMA), wideband IS-95

WAP is fundamentally different than broadband technologies. While delivering wireless data, it does not have the bandwidth to deliver leased line replacement or to support broadband technologies. However, WAP has the potential to increase the mobility of many subscribers and enable a host of data applications to be delivered for enhanced services to subscribers.

1.9 Bluetooth

Bluetooth is a wireless protocol that operates in the 2.4-GHz industrial-scientific-medical (ISM) band allowing wireless connectivity between mobile phones, PDAs, and other similar devices for the purpose of information exchange. Bluetooth is meant to replace the infrared telemetry portion on mobile phones and PDAs enabling extended range and flexibility in addition to enhanced services.

Because Bluetooth systems utilize a radio link in the ISM band there are several key advantages to this transport protocol. Bluetooth can effectively operate as an extension of a local area network (LAN) or a peer-to-peer LAN and provide connectivity between a mobile device and the following other device types:

- Printers
- PDAs
- Mobile phones
- Liquid-crystal display (LCD) projectors
- Wireless LAN devices
- Notebooks and desktop personal computers

One of the key attributes that Bluetooth offers is the range that the system or connection can operate over. Since Bluetooth operates in the 2.4-GHz ISM band, it has an effective range going from 10 to close to 100 meters (m). The protocol does not require line of sight for establishing communication. Its pattern is omnidirectional, thereby eliminating orientation issues, and can support both isochronous and asynchronous services paving the way for effective use of TCP/IP communication.

Bluetooth is different than the wireless LAN protocol 802.11 and WAP but again looks at delivering data connectivity over radio. Bluetooth is also different because of the applications, use of the unlicensed band, and focus on end-user devices. Bluetooth is meant to be a LAN extension fostering communication connection ease for short distances.

1.10 Wireless LAN (802.11)

Wireless LAN (WLAN) is another wireless platform enabling various computers or separate LANs to be connected together into one LAN or WAN. A big advantage is that WLAN-enabled devices do not need to be physically connected to any wired outlet, which allows for location flexibility as shown in Fig. 1.9.

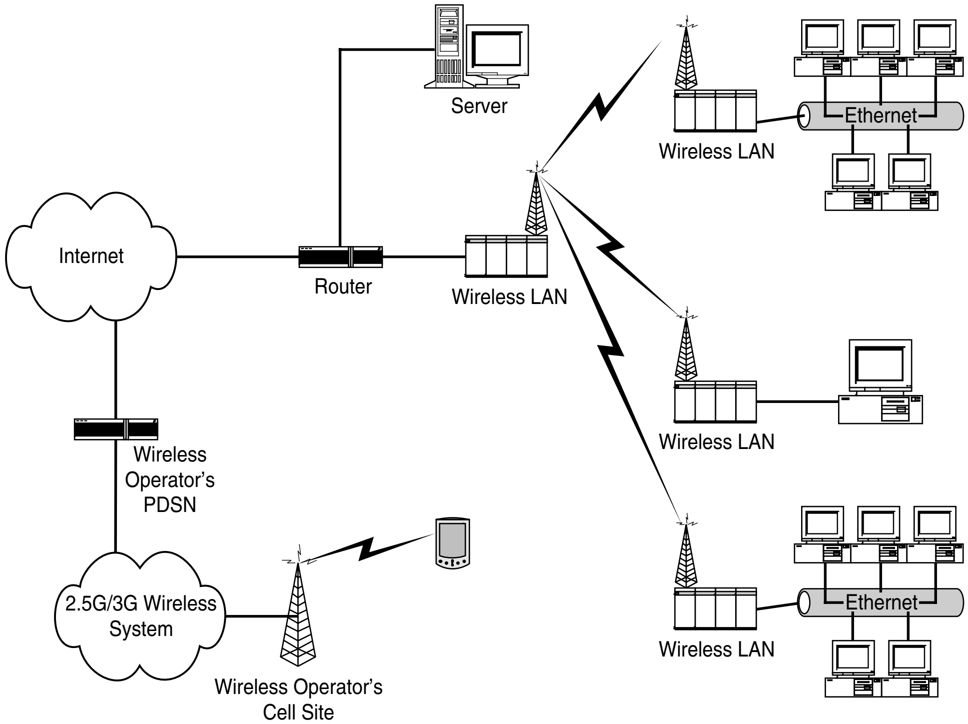

Figure 1.9 WLAN.

The convergence of WLAN 802.11 with wireless mobility has been described as the "real killer application." This means that it will truly allow the subscriber to take advantage of all the applications available on the World Wide Web while at the office, home office, or on the road at some unknown location, provided, of course, there is coverage. The issue of security and provisioning to make this a reality is not a trivial matter if true transparency (requiring no user intervention) is desired with the intranet of a company by its sales and support staff.

There are several protocols that fall into the WLAN arena. Not all of them are compatible, which leaves the possibility of local islands (when the protocols cannot communicate with each other unless a device provides translation) being established. The most prevalent WLAN protocol is IEEE 802.11, but Bluetooth is also referred to as a WLAN protocol. 802.11 is an Institute of Electrical and Electronics Engineers (IEEE) specification encompassing several standards; some of the more prevalent ones are 802.11a, 802.11b (WiFi), and 802.11g.

What is interesting is that 802.11a operates in the 5-GHz, unlicensed national information infrastructure (UNII) band, while 802.11b and 802.11g operate in the 2.4-GHz ISM band along with Bluetooth. 802.11g specifically is meant to increase the data rate to 54 Mbit/s while providing backward compatibility for 802.11b (WiFi) equipment. What this means is that 802.11g equipment operating in the 2.4-GHz band can operate at speeds previously enjoyed by 802.11a equipment in the 5-GHz band. To complicate matters there are a host of other 802.11 specifications, all which either exist or are in the process of being standardized.

The 802.11 specifications were designed initially as a wireless extension for a corporate LAN for enterprise applications, and numerous devices have been manufactured to this specification. For example, the 802.11b protocol is a shared medium and utilizes a listen-before-talk protocol called collision sense multiple access/collision avoidance (CSMA/CA).

Table 1.2 is a simple comparison between the key 802.11 protocols and Bluetooth. Both 802.11b and Bluetooth utilize the ISM band, but their formats and purposes are different. However, 802.11a operates in the UNII band and can operate at a much greater effective radiated power (ERP). Basically 802.11 devices are meant to cover a wider area than Bluetooth devices, and 802.11 devices have the potential for higher throughput. The data rate in the chart for 802.11a and b shows a range of speeds, which, of course, are dependent upon the modulation format used, available power, and interference experienced.

IEEE 802.11 is important for wireless mobility because it provides direct mobile data interoperability between the LAN of a corporation and the wireless operator's system. The inclusion of expending the corporate IP-PBX has great potential. Presently there have been many demonstrations and some operational systems regarding this integration of wireless mobility and wireless LANs which require application-specific programs to enable the interoperability.

TABLE 1.2 Comparison between Key 802.11 Protocols and Bluetooth

WLAN	802.11a	802.11b	Bluetooth
Transport	5-GHz UNII DSS	2.4-GHz ISM FHSS/DSS	2.4 GHz ISM FHSS
Data rate	6–54 Mbit/s	1–11 Mbit/s	1 Mbit/s
Range	*	50 m	1–10 m
Power	0.05/0.25/1 W	+20 dBm	0 dBm

*If used with an external antenna, the WLAN can be extended beyond the immediate office environment.

Note: DSS = direct sequence spread spectrum, FHSS = frequency-hopping spread spectrum, W = watts, dBm = decibels referenced to 1 milliwatt.

There is also another WLAN specification, HiperLan/2, which was developed under the European Telecommunications Standards Institute (ETSI). HiperLan/2 has similar physical layer properties as 802.11a in that it uses orthogonal frequency-division multiplexing (OFDM) and is deployed in the 5-GHz band. The media-specific access control protocol (MAC) layers are different; hence, the different technology specification in that HiperLan/2 uses a time-division multiple access (TDMA) format as compared to 802.11a which uses OFDM.

1.11 VoIP

Voice over IP has provided, and continues to provide, a viable alternative for call delivery of voice traffic. It is interesting that most of the initial VoIP implementations have not occurred over the Internet but rather over corporate LANs and private IP networks like long-distance providers. Private implementation has mitigated the QOS problems associated with VoIP on the Internet.

In many circles, the mention of VoIP invokes quality concerns due to delay and jitter problems when the access medium is over the public Internet. As mentioned previously though, the true application for VoIP is as a transport medium over private or dedicated pipes or networks where the QOS issue no longer is an issue.

The original standards activity for VoIP was defined in ITU H.323 which has the title “Packet-Based Multimedia Communication Systems.” This standard’s wide use was a direct result of its being offered as freeware by Microsoft. There is, however, an alternative standard in competition with H.323: the media gateway control protocol (MGCP), also called the single gateway control protocol (SGCP). SGCP assumes a control architecture similar to that of the current PTT voice system where the control elements are located outside the gateway itself. These external call control elements are referred to as call agents.

Wireless and CLEC operators that utilize the IP-based infrastructure only can also provide voice services as part of their offering if the proper QOS and delivery issues are addressed in the design and service offering. Wireless operators offering circuit emulation service (CES) voice services provide an attractive entry point for customers. However, the fact that VoIP is being used does not need to be conveyed to the customer if the proper delivery and QOS issues are addressed. A primary reason that VoIP is so attractive for a wireless operator is not solely related to the interconnect savings that may be achieved, but in saving the spectrum, since IP traffic is by itself dynamic in its bandwidth utilization.

Figure 1.10 depicts the major components involved with providing VoIP, either as a direct service or as an alternative transport medium that the wireless operator uses to be more cost competitive or better yet to improve the margin. As Fig. 1.10 suggests, VoIP can be delivered either directly to a public data network or via the Internet depending on the service-level agreement (SLA) used. In addition, the diagram depicts the issue of the operator using VoIP as a medium for handling voice traffic into the switching complex where it then converts the IP traffic into classical TDM traffic for interfacing to the PTT for call delivery.

Figure 1.11 depicts the connection between a wireless operator in one market and its operation in another market. The diagram can, of course, be meant for an ISP, CLEC, or large corporation.

Voice over IP is the most flexible choice for voice transport since it can run over any layer-one or layer-two infrastructure. This flexibility is particularly important in heterogeneous environments like LMDSs.

1.12 Typical Central Office

Figure 1.12 is a generic mobile telephone center configuration. The mobile switching center (MSC) is the portion of the network which interfaces the radio world to the public switched telephone network (PSTN). In mature systems there are often multiple MSC locations, and each MSC can have several cellular switches located within each building.

A mobile telephone switching office (MTSO) is commonly referred to as the MSC and is anything but typical. Although a MSC typically delivers voice services, the particular services that can be offered and delivered are extremely varied. For example, in AMPS only voice services could be delivered. GSM system voice along with short messaging service (SMS) services would be provided. However, with the advent of Internet and 2.5/3.0G (packet-based mobile) services, many residential MSCs which primarily delivered voice services are now transitioning from a circuit-switching to a packet-switching system.

A simplified example of a typical MSC layout is shown in Fig. 1.12. Naturally, when determining the dimensions and specific equipment required for the facility, one will need to factor in the type of services to be provided as well as the time frame the design is to encompass (i.e., the growth potential needed).

Typically a MSC consists of an equipment room, toll room, power room, and operations room. The functions of each room are unique. The equipment room has the switching and packet platforms for treating and servicing the

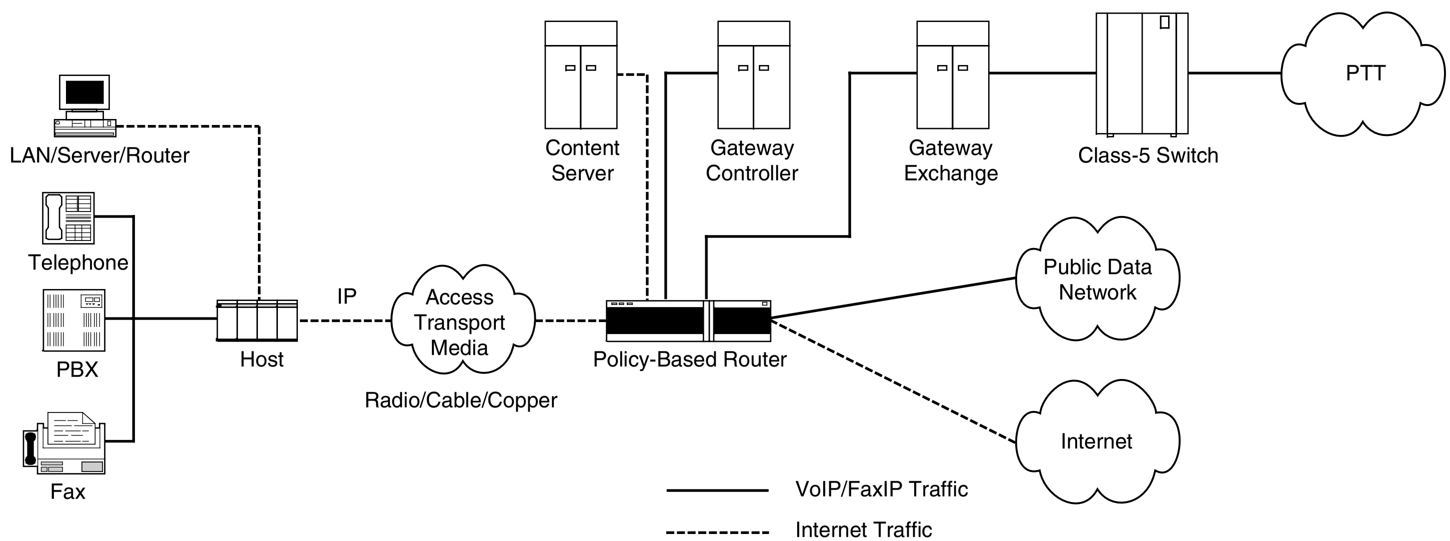

Figure 1.10 VoIP network.

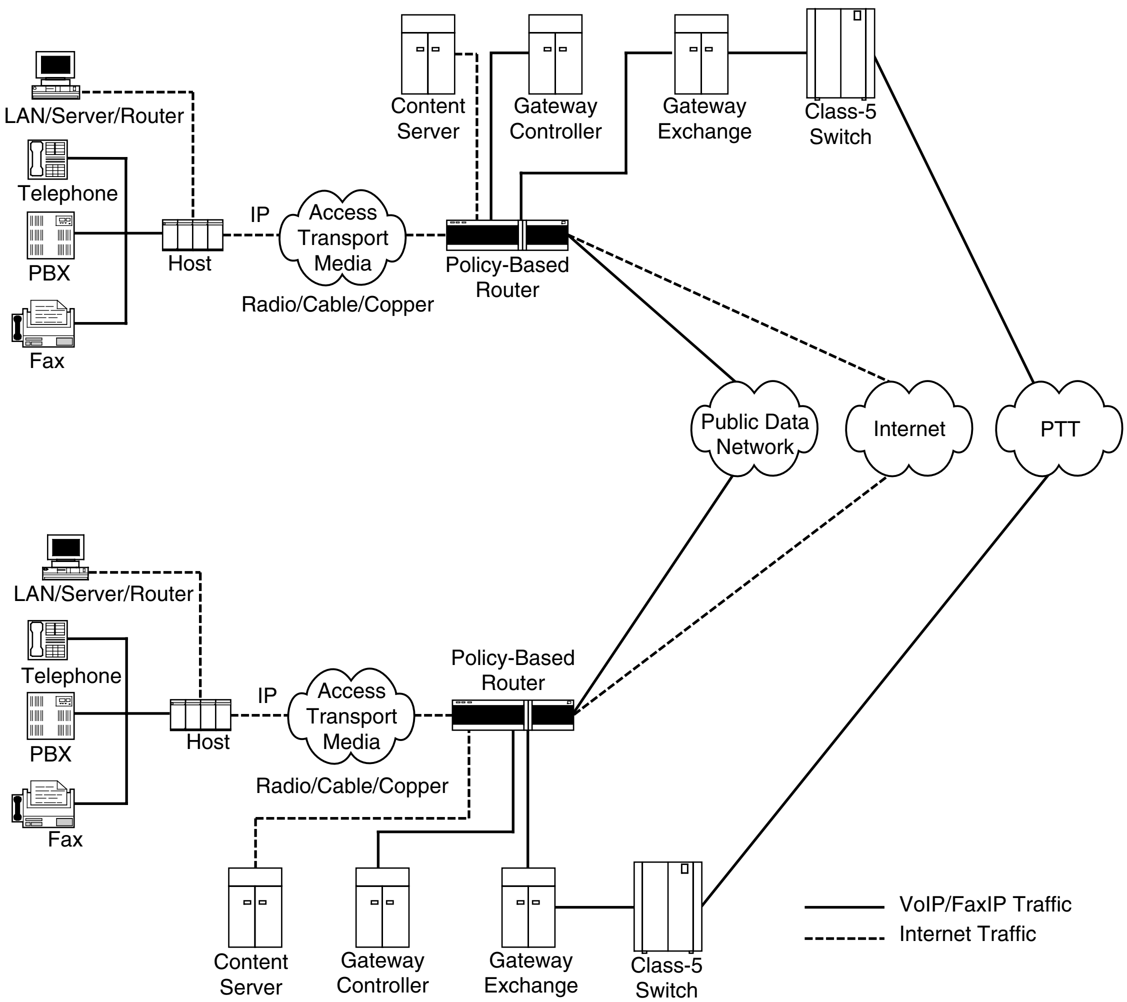

Figure 1.11 VoIP network.

subscriber's needs. The toll room, also referred to as the interconnect or telco room, is the area of the MSC where the system interfaces to the PSTN, CLECs, interexchange carriers (IXCs), and other outside carriers. The purpose of the toll room is to provide the portal for entry and exit of services for the central office. The power room usually houses the rectifiers, batteries, and generator for emergency backup purposes. The operations center is the area where the craft personnel perform the data entry and monitoring and maintenance of the network itself.

The following list of topics should prove helpful in establishing the resources and timing needed for a fixed network design to be successful.

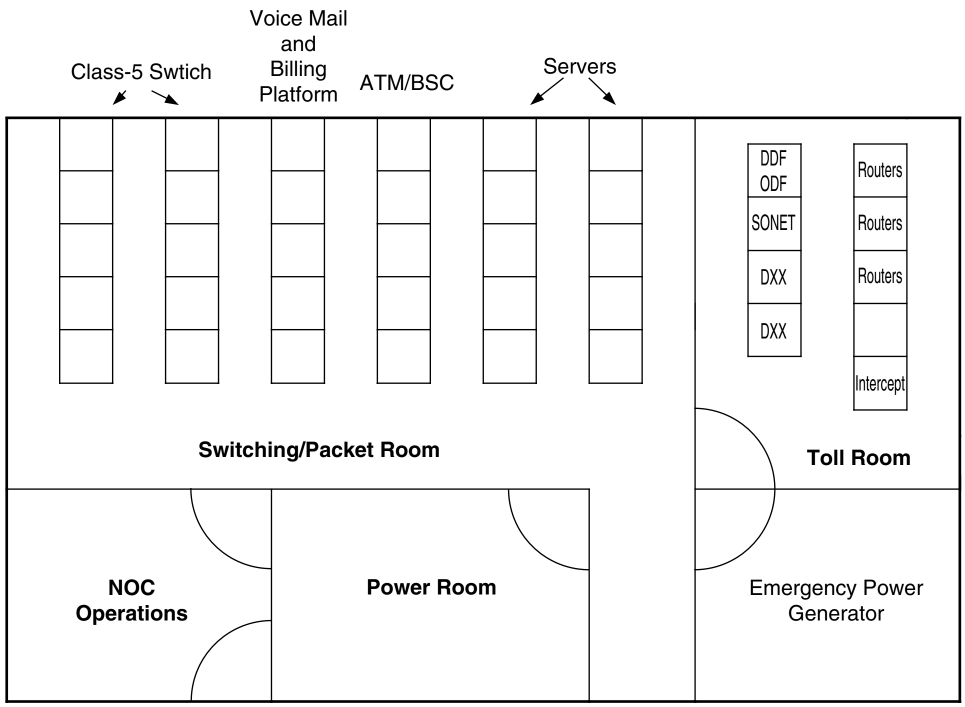

Figure 1.12 Typical CO layout.

Equipment room

- Class 5 switch
- ATM switches
- Voice mail system
- Servers
- Billing system

Toll room

- Signaling transfer point (STP)
- DXX (cross connect switch) equipment
- Routers
- Intercept equipment

This list does not address the issue of colocation with other service providers and the need to create a separate area for the operator to maintain and upgrade its equipment.