CHAPTER

3

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Access technologies

3.1 Access

WLL is all about providing access from the home into the switched network. As discussed in Chapter 2, WLL is only one of a number of competing technologies that can be used to provide access. In this chapter, all the existing and proposed technologies that are, or might be, used to provide local loop access are introduced, along with a short description of their key strengths, shortcomings, and likely costs. Most access technologies merit a book in their own right; indeed, books are available on many of the topics. This chapter is intended only to provide sufficient information that WLL operators will be able to better understand the competition they face.

An overview of the different access technologies is provided in Figure 3.1. The key technologies are explained in more detail throughout this chapter.

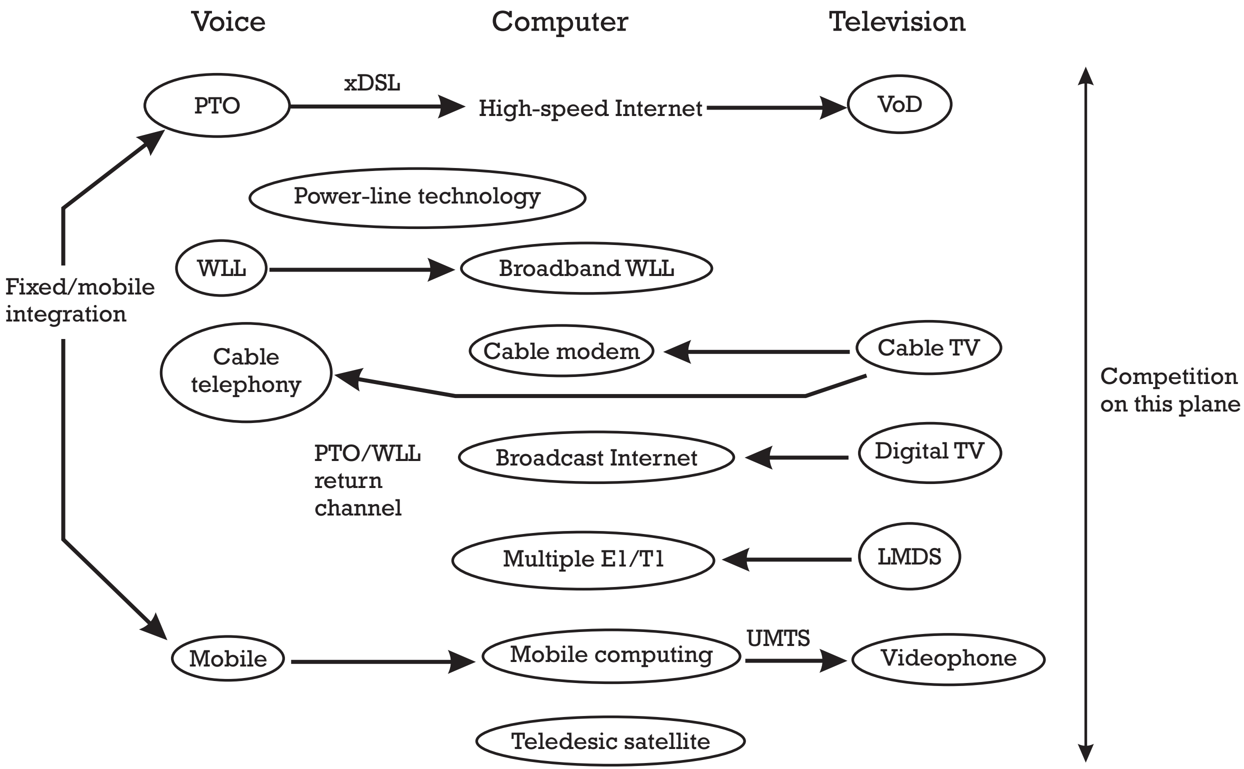

Figure 3.1 Overview of different access technologies.

3.2 Access via twisted pair

3.2.1 Voiceband modems

The twisted pair can be used directly to provide voice communications. To provide data communications, it is necessary to make use of a device that converts the data signal into a format suitable for the telephone channel. Such a device is known as a modem, a shortened form of the term *modulator-demodulator*. A modulator takes the digital waveform and maps it onto an analog signal that looks to the telephone system somewhat like a voice signal. The demodulator reconverts the signal into a digital signal. A detailed description of telephone modems can be found in [1].

The telephone channel has a bandwidth of about 3 kHz. It also has a relatively good signal-to-noise ratio (SNR) of some 30 to 40 dB. That means that although only some 3,000 symbols per second can be transmitted, each symbol can contain a relatively large amount of information. Instead of representing just two different levels, as is normal in digital modulation, it could represent, say, 16 or 32 different levels. The modulation used to achieve this is termed quadrature amplitude modulation (QAM).

Voiceband modem standards are developed by the ITU. Standards are important in this area because the modulator and the demodulator are installed in different premises, often in different countries, and they need to know how to work with each other. The standards are updated as technical progress allows. Each is known by a number, such as V.33. The letter *V* is common to all modems, while the number that follows tends to increase as each new modem is introduced. However, there are other entities that the ITU standardizes within the V series, such as interconnection arrangements. Therefore, not all V.xx numbers represent modems, and the modem numbers do not necessarily rise consecutively. An example of how the standards have progressed is shown in Table 3.1.

The most recent standards allow data rates of up to 33.6 Kbps, with the latest modem to be announced capable of rates up to 56 Kbps, depending on the quality of the channel. This recent progression reaches the theoretical maximum rate of information transfer on the band-limited twisted wire; hence, no further improvement in speed can be expected. (Subsequent sections discuss techniques that achieve much higher data transfer rates, but such techniques work only when the 3-kHz band-limiting filters are removed by the PTO.)

Table 3.1
Summary of Voiceband Modems

Data Rate (Kbps)	Symbol Rate (Baud)	Modulation Type	Standard
2,400	1,200	4-DPSK	V.26, 1968
4,800	1,600	8-DPSK	V.27, 1972
9,600	2,400	16-QAM	V.29, 1976
9,600	2,400	32-QAM	V.32, 1984
14,400	2,400	128-QAM	V.33, 1988
33,600	4,800	256-QAM	V.34, 1996

The key advantages of voiceband modems are the following:

- The economies of scale achieved have resulted in a cost per modem of around $200 each.
- They can be connected directly to a telephone line with no need for the PTO to modify the line in any manner.

The key disadvantages are the following:

- They need a dedicated line for the time they are in use; hence, voice calls cannot be made or received on the telephone line.
- The maximum capacity is around 56 Kbps, which is relatively slow for computer data transfer.

3.2.2 ISDN

Integrated Service Digital Network (ISDN) basically is a framing format that allows data to be carried at a range of data rates across a bearer. ISDN makes use of the fact that twisted-pair cables can carry more information if the problems of cross-talk can be overcome. To provide ISDN access, the PTO first must remove filters on the line that prevent signals of bandwidth greater than 3 kHz being transmitted. There is an installation cost involved, which the user must pay. An ISDN modem is then installed at both ends of the line.

Not all lines are suitable for ISDN. Older lines, or lines over 3 km, typically cannot carry ISDN because the cross-talk with other lines is too severe or the signal attenuation too great. A test on the line is required before ISDN service can be provisioned.

ISDN is an international standard that provides a range of data rates. The lowest rate ISDN channel is 64 Kbps, with a typical ISDN deployment providing a so-called 2B + D arrangement (known as basic rate ISDN access, or BRA). There are two basic (B) 64-Kbps channels and one data (D) channel of 16 Kbps. The data channel can be used to provide signaling information, while both basic channels are in use. Hence, a 2B + D channel provides 144 Kbps. Primary rate ISDN offers 30B + 2D channels, a total of nearly 2 Mbps, but cannot be provided over twisted-pair copper; instead, new coax cable is required. Basic rate modems cost around $300 each, although prices are expected to fall significantly in the coming years. More information on ISDN can be found in [2] and [3].

The advantages of ISDN include the following:

- It is a long-established standard and a proven technology.
- It is relatively cheap and widespread in some countries.

The disadvantages include the following:

- Only a small increase in the rate is offered by voiceband modems.
- ISDN may be rapidly outdated by xDSL technology.

3.2.3 xDSL technologies

The area of digital subscriber line technologies is a relatively new one (the abbreviation *xDSL* refers to all the approaches to digital subscriber lines). The concept, like ISDN, is to use existing twisted pair, less any filters that may be in place, to provide significantly greater data rates through complex intelligent modems capable of adapting to the channel and removing any cross-talk that might be experienced. The term *xDSL* has come about to encompass a host of proposed different approaches, such as asymmetric digital subscriber line (ADSL), high-speed digital subscriber line (HDSL), very high-speed digital subscriber line (VDSL), and doubtless more to come.

Research has shown that these technologies can offer up to 8 Mbps, perhaps more, depending on the quality of the existing twisted pair. Readers at this point may be asking themselves why on the one hand the twisted pair can provide only 56 Kbps and on the other hand the same twisted pair can achieve 8 Mbps. The reason has to do with the manner in which cross-talk is treated. Voiceband modems overcome the problem of cross-talk by ensuring that none is generated. The xDSL technologies generate significant cross-talk but employ advanced technology to cancel its effects. It is that difference in approach, enabled by advances in digital signal processing, that has allowed xDSL to make such dramatic improvements in the data rates that can be achieved.

The first of the xDSLs to appear was HDSL, which provides up to around 768 Kbps on a single twisted pair. It also can make use of a number of twisted pairs to deliver higher rate services by, for example, sending every even bit down one cable and every odd bit down another. Using up to a maximum of three twisted pairs, a maximum data rate of around 2 Mbps in both directions can be achieved with only modestly complex equipment. A major difficulty associated with HDSL is the removal of echoes from the signal, which can cause intersymbol interference. The echoes are removed by equalizers. Equalizer design is a complex topic that attempts to balance complexity and delay against performance. In HDSL, a combination of preequalization at the transmitter and equalization at the receiver is used. The preequalization attempts to transmit a signal that when received has no echoes, while postequalization removes any residual error effects.

HDSL is intended for business applications. HDSL signals can propagate only a few kilometers along twisted pairs. Most businesses, however, are relatively close to their nearest exchange, so that is not a significant limitation. HDSL typically is less suitable for residential applications because homes may be at much greater distances from the local exchange.

After HDSL came ADSL, which provides more data in the downstream direction than in the return path. This asymmetry meets the requirements of Internet access well, where more information is passed to the home than is sent into the network from the home. By restricting the return path to lower rates, less near-end cross-talk (NEXT) is generated. NEXT is interference from the return signal that contaminates the received signal. Because the return signal is at a lower rate, the effect of NEXT is reduced and higher downstream rates achieved. ADSL promises to provide up to 8 Mbps downstream but only tens of kilobits per second upstream. Current trails are achieving around 1.5 Mbps downstream and 9.6 Kbps on the return path.

ADSL works by dividing the transmitted data into a number of streams and transmitting the streams separately at different frequencies. This approach is known as discrete multitone (DMT) in the fixed-line community; however, the technique has been used for many years in mobile radio, normally known as frequency division multiplexing (FDM) or orthogonal frequency division multiplexing (OFDM). Indeed, this is the technique proposed for digital audio broadcasting and digital terrestrial TV broadcasting. For a detailed discussion of this approach, see [1]. This approach has the advantage that each transmitted data stream is narrowband and does not require equalization. The capacity of each stream can be adjusted according to the frequency response of the channel at that particular point. It also tends to improve error performance against impulsive interference because an impulse now damages a fraction of one bit on all the channels instead of a number of sequential bits on a higher rate channel. However, additional complexity results from the need to have an echo canceler for each channel and to modulate the multiple channels onto the single telephone line.

ADSL is more appropriate for residential applications than the other xDSL technologies. By reducing NEXT, the range achieved is greater than that for HDSL, allowing long residential lines to carry ADSL successfully. Also, the asymmetrical signal typically is suitable for residential applications such as VoD, in which more signal is sent to the home than received from it. It is estimated that up to 70% of all residential lines in the United States could be suitable for ADSL operation.

Finally, VDSL has been proposed where fiber to the curb (FTTC) has been deployed. In that case, the copper run to the subscriber's premises is very short, typically less than 500m; hence, higher data rates can be supported. Using the most advanced technology proposed yet, it is suggested that VDSL could achieve data rates of up to around 50 Mbps, although that is still far from being proved. Current plans suggest 10 Mbps downstream and 64 Kbps on the return path. VDSL cannot be used in networks in which FTTC has not been implemented.

xDSL will be expensive to implement, even though the local loop will stay relatively unchanged. The PTO will need to install new optical cable from the switch to a new cabinet in the street, as shown in Figure 3.2. Modems for xDSL are predicted to cost around $500 each, although the price in the coming years will depend heavily on the success of the technology and the economies of scale achieved.

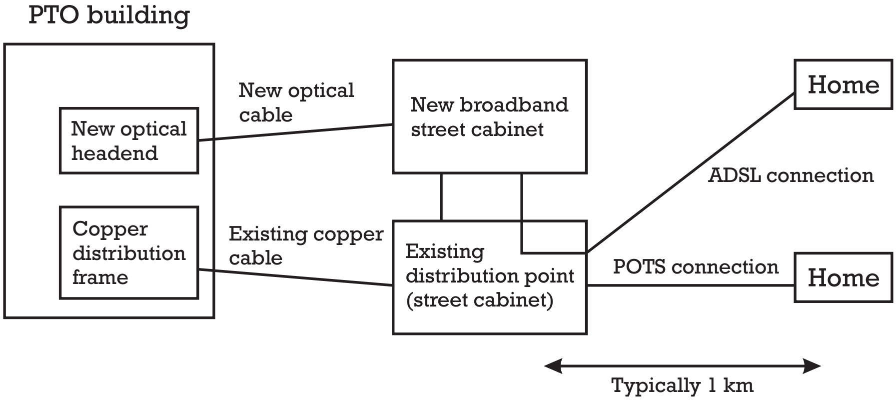

Figure 3.2 Modifications required to install xDSL technologies.

A problem with all the xDSL technologies is that the data rate that can be achieved depends on the length and the age of the twisted pair. As the length gets longer, the data rate falls. As yet, it is not clear what percentage of lines will be of sufficient quality to accept xDSL signals. Figures quoted in the industry vary from around 60% to 90%. Due to the technology's relative newness, texts on xDSL are hard to find and tend to be limited to chapters in books such as [4]. Readers who want to know more about this topic should refer to academic journals such as [5] and [6].

During 1998 there was a change of direction from the ADSL forum. In the light of many potential problems associated with very high speed transmission, the forum decided to work on a new version of ADSL called ADSL Lite, or Universal ADSL (U-ADSL). The concept was that by reducing the maximum transmission rate, the distance over which ADSL signals could be transmitted would increase as would the tolerance to old or poorly maintained copper. Further, once the signal reached the user's home, there would be no need for expensive internal decoders and for the home wiring to be upgraded to handle the data rates of up to 8 Mbps. This would save substantial cost since engineers would not need to be sent to users' homes to install the wiring. Most ADSL Lite manufacturers are working with maximum data rates of 500 Kbps. While this data rate allows much more cost-effective installation of the service, it does not offer the quantum leap that "normal" ADSL offered. At around three times the ISDN rate, ADSL Lite is an improvement but not necessarily one that all will view as sufficient to justify the expense of changing to a different technology.

A summary of the twisted-pair technologies is provided in Table 3.2.

The key advantage of xDSL is the potential extremely high data rate on existing ubiquitous lines.

The key disadvantages of xDSL are as follows:

- The modems are relatively expensive.
- The technology is unproven.
- It is unlikely to work for all homes.

There have been many varying predictions for ADSL. Some of those available at the start of 1999, extrapolated and placed on a composite chart, are shown in Figure 3.3. Specific predictions used in this figure and extrapolated where necessary were:

- Datamonitor predicted 5.5 million European households with xDSL lines by 2002.
- Ovum predicted 19 million xDSL lines worldwide by 2003.
- Dataquest predicted 5.8 million lines worldwide by 1999.
- International Data Corp predicted 2.5 million ADSL lines in the United States by 2001.

The figure shows reasonable agreement among the different analysts, when compared on a global basis, scaling pro rata to the percentage of

Table 3.2
Summary of Twisted-Pair Technologies

Technology	Speed Rate	Mode	Applications
Voice modems	56 Kbps	Duplex	Data comms
ISDN	144 Kbps	Duplex	Voice and data
HDSL	1.5–2 Mbps	Duplex	WAN, LAN
ADSL Lite	500 Kbps	Duplex	Internet, data
ADSL	1.5–9 Mbps 16–640 Kbps	To user To network	Internet, VoD, LAN multimedia
VDSL	13–52 Mbps 1.5–2.3 Mbps	To user To network	As ADSL plus HDTV

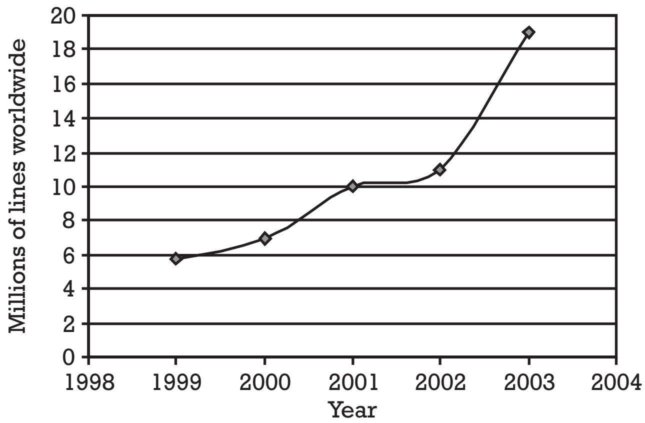

Figure 3.3 Predictions for ADSL lines installed worldwide.

world GDP for the region where the prediction was made. If the analysts are right, the number of ADSL lines should rise to nearly 20 million by 2003. However, as shown in Section 5.5, by this period there is expected to be around 50 million WLL lines. Hence, the current predictions are that in terms of lines, WLL will have a higher penetration than ADSL.

3.3 Access via coax

Cable operators have implemented what often is known as a tree-and-branch architecture. Figure 3.4 is a schematic representation of such an architecture.

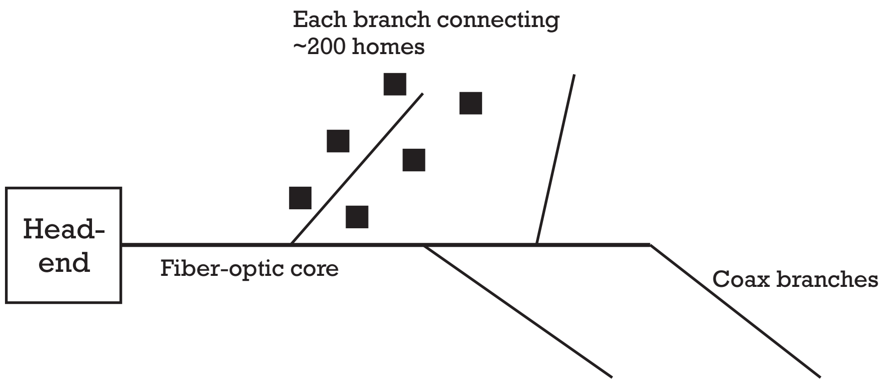

Figure 3.4 Tree-and-branch architecture.

Cable networks vary in their composition. Some networks are entirely coax, others use fiber optic in the backbone (the trunk of the tree) but coax in the branches. The latter networks are FTTC or hybrid fiber coax (HFC). Some postulated networks are composed totally of fiber, termed fiber to the home (FTTH). At present, the economics of FTTH are not favorable.[1]

While fiber has a virtually unlimited bandwidth (on the order of gigabits per second), coax has a bandwidth of up to around 750 Mbps in the existing installations.[2] With an analog TV picture requiring some 8 Mbps of bandwidth, that still allows numerous TV channels. With just one analog channel, some 50 Mbps of data can be transmitted using similar QAM techniques to voiceband modems. Cable, then, offers much higher capacity than even the xDSL techniques over twisted pairs.

This is not quite the whole story. For each home, there is one (or two) twisted copper pairs running from the switch right to the home. In a cable network, all homes share the backbone resource and the resource of the branch of the tree to which they are connected. To put it another way, all homes on one branch are connected to the same cable, whereas they all are connected to their own individual twisted pair. That is fine while cable is delivering broadcast services, to be watched by many viewers simultaneously, allowing 50 or more TV channels. However, if each user on a branch wants a VoD service, then only 50 users could be accommodated on one branch, unlike twisted pair using xDSL, whereas many users as needed could be accommodated. Indeed, in a typical cable network, the bandwidth per home available is only around 31 kHz, although it is unlikely that all homes would be using a dedicated downlink resource at the same time.

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1. FTTH has been something of a Holy Grail for PTOs and the cable industry because of the assumption that it represents the ultimate possible delivery mechanism, capable of delivering gigabits to the home. However, it has been pointed out that FTTH is akin to powering a lawn mower with a jet engine: The job might get done a little faster, but the mechanism is overkill in a situation in which coax provides more bandwidth than most users can possibly require. FTTH is both expensive and problematic in that, unlike current telephony, power cannot be supplied along with the signal. Now that the PTOs are facing competitive situations and investments increasingly have to be justified, it seems unlikely that FTTH will be implemented in the next 20 years or more.

2. Coax cable can have much higher bandwidths, up to hundreds of gigahertz, but as the bandwidth required gets higher, the cable tends to be expensive and bulky and the distance between amplifiers drops. Most cable operators have selected 750 MHz as a compromise between bandwidth and cost.

Such a sharing of resources causes even more problems in the return direction. Not only is the return path shared among all the users who require it, significantly reducing the capacity, but further, each user introduces noise onto the return path. The switch sees noise from across the entire network, significantly reducing the SNR and hence information content that can be received. The noise is particularly severe at low frequencies, where it often is known as ingress.

Despite all those problems, cable modems are being installed with a downstream capability of 30 Mbps and an upstream capability of 10 Mbps for a price of around $200. In summary, the advantages of cable are as follows:

- It has relatively high speed capabilities while requiring little modification to the network.
- Revenues from telephony, broadcasting, and Internet access allow the network costs to be divided across more users.

The disadvantages include the following:

- Cable penetration varies from near zero in some countries to an average of around 30% (there is near-full penetration in a few countries).
- The tree-and-branch structure may mean that twisted-pair systems start to surpass cable networks in five years or so with higher bandwidth capabilities.

The Strategis Group predicted that there would be 4.5 million cable modems worldwide by the year 2000. Others predict cable modem sales approximately in line with ADSL modem sales. This would suggest that, like ADSL, cable will provide a serious challenge to WLL, but will remain a less popular means of connection.

3.4 Access via TV broadcast

TV signals currently are broadcast via terrestrial transmission, satellite, and cable. Cable access was discussed in Section 3.3. This section looks briefly at terrestrial and satellite broadcasting.

Terrestrial broadcasting uses about 400 MHz of radio spectrum in the UHF frequency band (typically 400 to 800 MHz in most countries). However, the same spectrum cannot be used in adjacent cells because interference would occur. The spectrum typically needs to be divided into clusters of 11 cells to avoid interference, that is, each cell has around 36 MHz of spectrum. Some cells cover millions of users, with the result that each subscriber has only a few tens of hertz. Thus, providing individual services for each subscriber, such as VoD, clearly is not going to be possible.

Satellite is in a similar situation. It has more spectrum, around 1 GHz in total, and does not need to divide that spectrum among different cells in the same manner as terrestrial. However, compared to terrestrial, its cells are even larger, covering over 100 million users, so again individual services for subscribers are not possible.

Neither delivery mechanism can offer a return path. Service providers for both mechanisms postulate that they might use the twisted copper of the PTOs for the return paths, but they would get limited revenue and would have difficulty truly integrating their services. So, as an access method, both leave a lot to be desired. Their main role, with the advent of digital TV, will be the delivery of broadcast data in relatively large volumes. That could speed Internet access to some of the most popular pages and provide information, such as newspapers, online. The key advantage of TV broadcasting is that large amounts of data can be downloaded to large volumes of subscribers.

The key disadvantages are as follows:

- It lacks a return path.
- It cannot deliver signals on a per-subscriber basis.

3.5 Access via mobile radio

3.5.1 Cellular systems

Cellular systems are now available in most countries in the world. Compared to the other delivery mechanisms discussed earlier in this chapter, the key difference for cellular is that it provides access to a mobile terminal as opposed to a fixed terminal. The key strength of cellular is the provision of voice calls when mobile. Although cellular has some data capabilities, with most second-generation solutions providing 9.6 Kbps in 1999 with enhancements up to around 100 Kbps by 2001, cellular systems do not have the capacity for widespread usage of high-rate data. Hence, it seems likely that cellular systems will be used for a subset of data applications including location-specific information (e.g., the address of the nearest hotel) and restricted Internet and intranet access while mobile.

A key question is the extent to which cellular operators can attack the fixed marketplace. Many analysts predict that by around 2005, more than half of all voice calls will be made from cellular phones, and given that many voice calls today are made from within the home, this implies that cellular phones will rapidly penetrate the home market.

Cellular operators have made many attempts to enter this home marketplace. Some cellular operators have attempted to attack the fixed access market using initiatives such as cut-price evening calls and high levels of indoor coverage. To date they have generally discovered that they cannot match the PTO on price and that the cost of providing excellent indoor coverage is extremely high. However, the cost of cellular calls is continually falling and the coverage and capacity is continually improving, and it is only a matter of time before cellular makes significant inroads on voice calls within the building.

In the long term it seems likely that, at a high level of simplification, most voice calls will transfer across to mobile phones. However, mobile phones are unlikely to have high data rate capabilities in the foreseeable future. Hence, residential users may well keep their fixed line for data applications such as Internet usage and use their cellular phones for voice calls. This suggests that the long-term future (perhaps from around 2003) for WLL in developed countries is to provide high-speed data applications, possibly with some voice backup capabilities. In the interim, as cellular prices remain higher than fixed-line costs, there will be a requirement for voice-centric WLL solutions for many years to come.

The most successful cellular system, the global system for mobile communications (GSM), offers voice or data, with maximum data rates of up to 9.6 Kbps. Future enhancements to GSM might raise the maximum data rates as high as 300 Kbps and improve the voice quality, but that rate is slow compared to the other access technologies and is expensive in call charges.

Other successful cellular systems include the cdmaOne standard and the IS-136, or “TDMA” cellular standard. Both have been used for

WLL, as discussed later, both in cellular frequency bands and other available bands. For example, IS-136 systems have been deployed in South America in the 400-MHz band as WLL solutions.

Cellular systems have many disadvantages as an access technology, particularly low capacity and high cost. In developed countries, it can be expected that for some time they will continue to fulfill the role of providing mobility but will not present significant competition to the other access methods. That is not as true in developing countries, where cellular operators can use the same system to provide mobile systems and WLL systems and thus realize economies in equipment supply, operation, and maintenance.

The roles that cellular-based systems have to play in WLL networks is discussed in more detail in subsequent chapters. Fixed mobile integration also may affect the selection of an access method and is considered in more detail in Chapter 22.

3.5.2 Cordless systems

Cordless systems are similar to cellular but typically are designed for office and local area use. The differences between cellular and cordless technologies are explained in more detail in Chapters 11 and 12. The key difference in their application as an access technology is that cordless technologies such as the digital enhanced cordless telephone (DECT) offer a higher data rate than cellular, up to some 500 Kbps, with fewer limitations on spectrum and hence expense associated with the call. However, because cordless technologies typically provide coverage only in buildings and high-density areas, they will be unlikely to have coverage for most access requirements. It is that lack of coverage that makes them inappropriate as an access technology. However, as we will see, when deployed as a WLL technology, cordless becomes viable as an access technology.

3.6 Access via WLL

At this point, a simple categorization of WLL into narrowband and broadband is used. As we will see in later chapters, there is considerably more complexity than this.

3.6.1 Narrowband systems

Because the remainder of this book discusses WLL as an access technology, it is inappropriate to provide too much detail at this point. Instead, the key statistics, advantages, and disadvantages are provided to allow a comparison to be made at the end of the chapter. A wide range of WLL systems provides access rates of 9.6 Kbps through to around 20 Mbps. WLL systems have the following advantages:

- There is an economic provision of service in a wide range of environments.
- Moderate bit rates allow simultaneous voice and data in some cases.

They have the following disadvantages:

- Bit rates will not allow multiple simultaneous high-speed connections.
- A lack of existing infrastructure means new networks need to be built from scratch.

3.6.2 Broadband systems

As will be discussed in Chapter 14, an enhanced form of WLL technology that is on trial uses local transmitters to deliver TV signals and broadband data. Those trial systems are called local multipoint distribution systems (LMDS) and transmit in the 28-GHz band, where around 2 GHz of spectrum has been allocated. They typically provide multiple 2-Mbps E1 or T1 links. LMDS systems have the following advantages:

- Relatively high data rates;
- Capable of providing video, telephony, and computer data thus maximizing the revenue;
- Relatively low cost in comparison with cable alternatives.

They have the following disadvantages:

- Relatively high cost;
- Short range from the base station, requiring a relatively large number of base stations.

3.7 Access via power-line technology

This is an area still very much in its infancy. The idea is to send relatively high data rate signals along the existing electricity cables that connect most homes, placing the signal on top of the power supply signal. To enable this, a number of problems must be overcome, including the following:

- Power lines are generally not well insulated from loss of high-frequency signals and as a result high power levels and low ranges can be a problem.
- Signal leakage results in electromagnetic interference, which can be problematic to users of the radio spectrum.
- High levels of noise can be experienced on power supply lines as a result of switching and operation of commercial appliances.
- Like cable systems, the bandwidth is shared among all the users connected to the same electricity substation.

Despite these disadvantages, there are some clear advantages. The main one is the use of an existing resource providing a direct connection to subscribers. Another is the avoidance of the need to use radio spectrum. At present, those working in this area estimate that they may be able to produce a maximum data rate of around 1 Mbps, shared between up to 200 users, which, if used for activities such as Internet access, could, in a typical usage scenario, give each user the impression that he or she had access to a data rate of some hundreds of kilobits per second.

It is likely that the first commercial systems will become available during the year 2000 at which point it will be possible to assess the real level of opportunity posed by power-line technology.

3.8 Summary of access technologies

Table 3.3 provides a summary of all the access technologies discussed in this chapter.

The next part of the book examines in more detail the environments and economics of WLL and shows why predictions for WLL networks are currently showing rapid growth.

Table 3.3
Comparison of Different Access Technologies

Access Technology	Data Rates	Advantages	Disadvantages
Voiceband modems	<56 Kbps	Low cost, immediate installation	Blocks telephone line, relatively low data rates
ISDN	<144 Kbps	Proven technology, relatively cheap	Only small improvement over voiceband modem, may be outdated rapidly
xDSL	<8 Mbps downstream, around 100 Kbps return	High data rate on existing lines	Unproven, expensive, and will not work on all lines
Cable modems	30 Mbps downstream, 10 Mbps return	Relatively cheap, allows convergence	Cable only has limited penetration, architecture limits simultaneous users
TV distribution	Unknown, perhaps 10 Mbps downstream	Download of large data volumes to multiple subscribers	No return path, difficult to address individual homes
Mobile radio	64 Kbps cellular, 500 Kbps cordless	Can be used immediately where coverage is available	Limited data capabilities, cost, lack of coverage
Telephony WLL	<384 Kbps although some broadband systems provide 4 Mbps	Economic to provide, reasonable data rates	High data rates not possible, new infrastructure required
Power-line technology	<1 Mbps	Uses existing cabling	Not clear how effective the technology will be
LMDS	E1 or T1 multiples	High data rates at low cost	Minimal return path, short range

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