AT&T WIRELESS

White Paper

WIRELESS DATA NETWORKS COMPARISON

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Introduction

This paper provides a broad overview of the various wireless data services that are available in the United States and abroad. Wireless data is commonly referred to in the wireless industry as wireless IP or wireless Internet. This paper contrasts mobile data services between different types of cellular networks. It also examines wireless wide-area networks (WANs) that are not based on cellular technology, nor necessarily based on Internet protocols. It presents a road map that shows how cellular networks will evolve from their current generation of digital technology to what are called two-and-a-half- (2.5G) and third-generation (3G) cellular technologies, and how AT&T Wireless will participate in these global developments. As this paper makes clear, AT&T Wireless (AW) has a well-defined road map for compelling new wireless data services using 2.5G and 3G technologies.

AW currently offers wireless data service using the AT&T Wireless IP® network. The AT&T Wireless IP network is based on a technology called Cellular Digital Packet Data (CDPD) that uses the Transmission Control Protocol/Internet Protocol (TCP/IP). The network provides the data communications channel for the popular AT&T Wireless PocketNet® service. It also allows notebook computers and PDAs equipped with wireless modems to access the Internet or private intranets using standard IP networking protocols and applications. More information about AT&T Wireless Data Service is presented in Appendix B: AT&T Wireless IP Network (CDPD).

Although CDPD is widely available, customers want to deploy more demanding applications. In response, AW is deploying a wireless technology called General Packet Radio Service (GPRS), a technology that offers faster performance than CDPD. GPRS is a noteworthy development being deployed by carriers worldwide. In the future, AW will deploy a third-generation wireless technology called Enhanced Data Rates for GSM Evolution (EDGE), a radio enhancement to GPRS that significantly boosts data rates. Beyond EDGE, AW plans to deploy cellular technology called the Universal Mobile Telecommunications System (UMTS). AW is working aggressively to operate and deploy wireless data services that address customer needs and are based on the same worldwide standards that hundreds of other operators have chosen, allowing for a common data experience worldwide.

This paper describes and compares the various networks. The appendices provide additional details.

Wireless Network Overview

Before discussing the features of specific types of wireless data networks, it is helpful to understand the general capabilities of wireless networks and how they are evolving. Some networks, such as those based on cellular technology (e.g., from AT&T Wireless and Verizon), provide both voice and data services, whereas other networks (e.g., the Aerie Networks Ricochet™ network and those from Cingular Interactive and Motient Corporation) provide data services only. This paper discusses both types of networks. Table 1 summarizes the principal networks introduced in this section and lists the expected typical data throughput that customers will obtain. For some technologies, the table also lists the peak data rates. The peak rate refers to the instantaneous rate at which data is communicated across the radio interface. Because multiple users share the radio interface and because of protocol overhead, average user throughput is lower than the peak rate, regardless of the technology used.

	Expected Typical User Data Throughput	**Availability**
2G cellular (e.g., CDPD, CDMA Wireless Web)	Circuit-switched and packet-switched services 8 Kbps to 13 Kbps	Now
2.5G cellular (e.g., GPRS, CDMA2000 1XRTT)	Packet-switched services Up to 60 Kbps (153 Kbps peak)	Initial deployments 2001; widely available 2002
3G cellular (e.g., EDGE, UMTS CDMA2000 1XEV)	Packet-switched services Up to 800 Kbps (2 Mbps peak)	Beginning in 2002 in select areas; widespread deployment occurring over the next five years
Dedicated packet networks (e.g., Cingular Interactive, Motient)	Packet-switched to 9.6 Kbps	Now
Two-way paging (e.g., WebLink Wireless)	Limited to short messages of about 100 to 500 characters	Now
Telemetry systems (e.g., Cellemetry®, Aeris.Net™)	Limited to very short messages of 32 bits	Now
Mobile satellite (e.g., Globalstar™)	Circuit-switched and packet-switched services 2.4 Kbps to 9.6 Kbps	Now and emerging

Table 1: Overview of wireless data networks

The first generation of cellular technology, analog cellular, was widely deployed in the 1980s. The second generation of cellular technology (2G), digital cellular, was deployed throughout the 1990s and is today the predominant cellular technology. Operators currently use three types of digital cellular technology in the U.S.:

- Global System for Mobile Communications (GSM), e.g., AW,Cingular and VoiceStream
- TIA/EIA-136, commonly referred to as TDMA (Time Division Multiple Access), e.g., AW and Cingular

- TIA/EIA-95, commonly referred to as CDMA (Code Division Multiple Access), e.g., Sprint PCS and Verizon

Beyond today's second-generation digital technology, operators are deploying 2.5G technologies like GPRS and 3G technologies like EDGE, UMTS and CDMA2000.

Examining data throughput speeds is an effective way to explain the capabilities of different generations of networking technology. Data throughput speeds are measured in bits per second, such as kilobits per second (Kbps) or megabits per second (Mbps).

Current second-generation cellular systems such as CDPD and GSM offer data services with throughput of about 14 Kbps. Beginning in 2001, increased data rates of up to 40 Kbps (effective user throughput) started to become common with networks such as the AT&T Wireless GPRS network. With technologies such as EDGE, effective user data rates will increase to as high as 120 Kbps (over 384 Kbps peak), and eventually as high as 800 Kbps (2 Mbps peak) with UMTS. This paper discusses the various second- and third-generation and 2.5G cellular technologies in the next section, "Cellular Data Services."

In the U.S., there are a number of noncellular wireless-data networks. Two wide-area networks are dedicated to packet data service: the Cingular Interactive network and the Motient network. These are fully deployed and offer services similar to AT&T Wireless IP, though not based on the Internet protocol (IP). Paging companies have upgraded their networks to offer two-way messaging service, while a couple of services have been deployed specifically for telemetry applications (Aeris.net and Cellemetry). Meanwhile, there are an increasing number of satellite options (e.g., Globalstar), though these generally make sense only when no terrestrial options are available. Data services are also becoming available for specialized mobile radio services like those offered by Nextel. All of these networks are described and contrasted with the AT&T Wireless IP service and GPRS services in the section "Noncellular Data Networks."

Cellular Data Services

This section explains how wireless data services operate in cellular networks, and how these services will evolve with new generations of cellular technology. First we discuss the different radio bands used by cellular networks, and then we explore how the data services will operate for the different types of cellular technologies.

Cellular networks were originally deployed in cellular radio bands (850-MHz band) with 50 MHz of spectrum available. In the late 1990s, the Federal Communications Commission (FCC) auctioned an additional 120 MHz of spectrum in the 1.9-GHz band called Personal Communications Service (PCS). Operators had to compete with one another for this spectrum, ultimately paying billions of dollars to secure this valuable resource. Though expensive, licenses give operators exclusive use of that spectrum in specific geographical areas and protect users from the types of interference they might experience with networks such as unlicensed wireless local-area network (LAN) technologies.

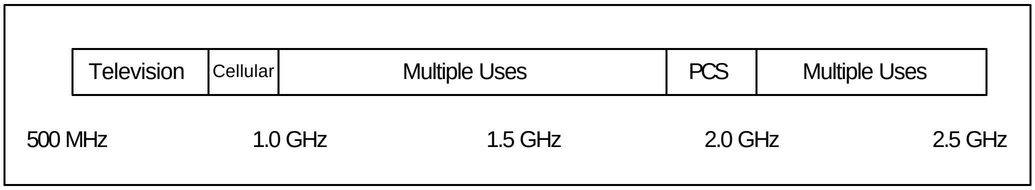


Figure 1: Cellular and PCS Spectrum

AW offers service in both the 850-MHz cellular and 1.9-GHz PCS bands, and refers to its service as Digital PCS. Except for the frequencies used, the cellular technology is identical between the two bands, and, from a user's point of view, service offerings (voice and data) are identical. In this paper, we simply refer to this type of technology as digital cellular technology, regardless of which radio band is involved.

Once 3G cellular technology is available, carriers will be able to deploy 3G technologies (e.g., EDGE and UMTS) in either existing radio bands or a new spectrum allocated for 3G services. The AW cellular technology strategy provides considerable flexibility in which spectrum it uses to deploy its next-generation networks. Both GSM and CDMA cellular technologies have well-defined evolution paths for data services. Though a similar evolution path has been specified for TDMA, AW has decided to implement its next-generation data services using GSM cellular technology.

Many GSM networks today offer circuit-switched data at about 13 Kbps. A few overseas operators offer a service called High-Speed Circuit Switched Data (HSCSD), which boosts speeds to 52 Kbps. Most, however, are in the process of deploying GPRS, a wireless IP technology with effective throughput as high as 40 Kbps.

CDMA networks today offer circuit-switched data capabilities at 13 Kbps in the U.S. Higher-speed packet service will come with a 2.5G service called CDMA2000 1X. Beyond that, CDMA operators are considering a technology called CDMA2000 1XEV.

Figure 2 shows the evolution of these data services.

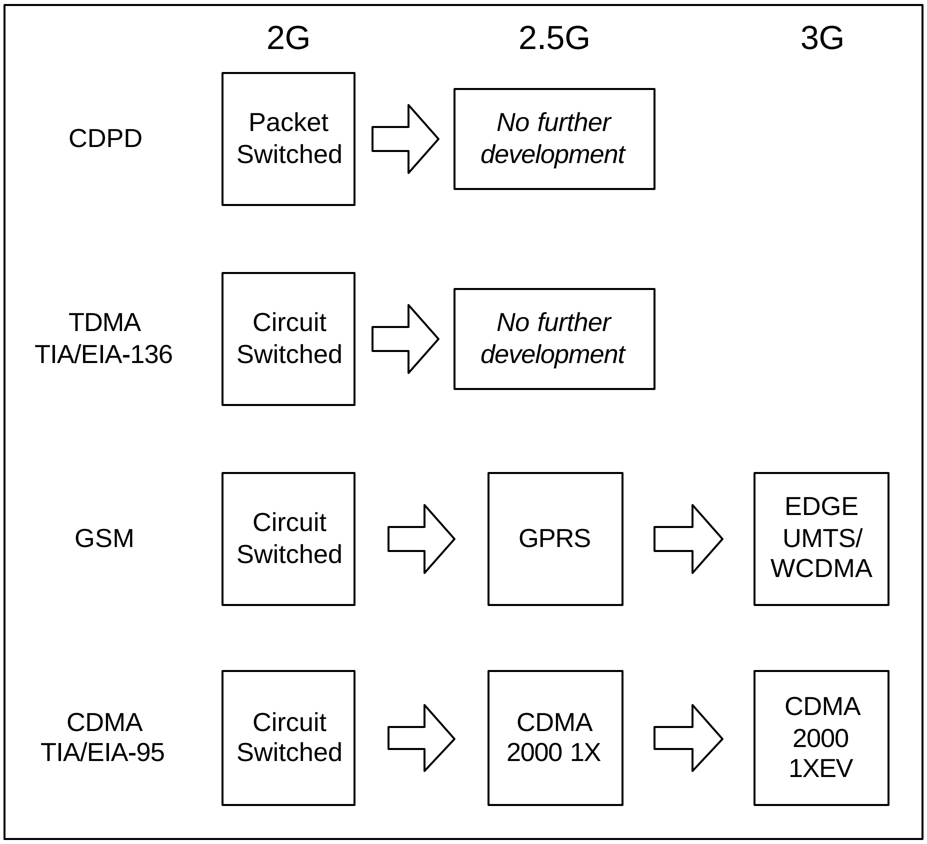


Figure 2: Evolution of Cellular Data Services

The subsections below discuss the particular cellular technologies in greater detail, beginning with a discussion of different types of cellular data services. See also Appendix A: Summary of Cellular Data Services.

Types of Cellular Data Services

In this section we explain the three types of data services available over cellular networks, including:

- Short message service (SMS)
- Circuit-switched data service
- Packet-switched data service

We also discuss the different types of user devices. Subsequent sections discuss each network technology (e.g., GSM) in detail and explain how the particular data services will be deployed. Refer also to Appendix A: Summary of Cellular Data Services, which provides a table summarizing the cellular data services discussed in this section.

Short Message Service

One common and very popular data service for digital cellular networks is called short message service (SMS). SMS messages are limited to about 150 characters and are similar to paging services from paging networks. Most digital (and PCS) cellular phones have an Internet e-mail address (e.g., 123456789@att.mobile.net) that allows messages to reach them from the Internet. SMS services are either one-way (mobile terminated) or two-way (mobile originated and mobile terminated). AW has enhanced its SMS service to support two-way communications. Since SMS messages are carried on digital-cellular control channels, they can be sent and received at the same time as voice and other types of data calls.

Note: SMS is not available for analog cellular networks.

Circuit-Switched Data

Circuit-switched connections provide a temporary, dedicated line (or circuit) between two end points. *Dedicated* implies that the circuit is not shared with any other users; *temporary* implies that the connection exists for the duration of the transmission only. A telephone voice connection is an example of a circuit-switched connection. A circuit is dedicated from the moment the caller dials a phone number and makes a connection until the caller and receiver hang up. Once the connection is terminated, the circuit becomes available for use by other parties. Carriers generally charge based on the number of minutes for circuit-switched data service, as opposed to the amount of data for packet-switched data service. GSM, CDMA and TDMA networks can all support circuit-switched data service.

Circuit-switched connections are appropriate for voice calls that tend to be long, two-way and highly interactive. This makes circuit-switched connections appropriate for data transactions that share similar characteristics. For example, an extended file transfer that requires the use of a network connection for a long period of time would be appropriate for a circuit-switched connection. However, for almost all applications, customers will prefer packet-switched data service because it is more reliable and involves shorter setup times.

When data is sent via a circuit-switched connection, all data is transferred at once from the source to the destination. Data is received in the order sent and is not likely to be lost, separated or incomplete.

At the mobile computer, the computer controls the mobile telephone using attention (AT) commands as if it were a conventional modem. One command, for example, instructs the telephone to initiate a data call. Users could choose a data-only modem instead of a mobile telephone if they wanted data communications only, not voice communications.

Over the radio link (also called the airlink), the mobile telephone and cellular network use specialized communications protocols to ensure reliable data communications. The mobile switching center connects the data call to a gateway that converts the data to conventional modem protocols, such as V.42 and V.90, for transport over the Public Switched Telephone Network (PSTN). This gateway is called a modem interworking function. At the other end of the connection (e.g., corporate or ISP modem pool), a conventional modem terminates the connection.

One can think of the combination of digital telephone, radio link, base station and switch center as an extension cord to the modems located at the interworking function. See Figure 3.

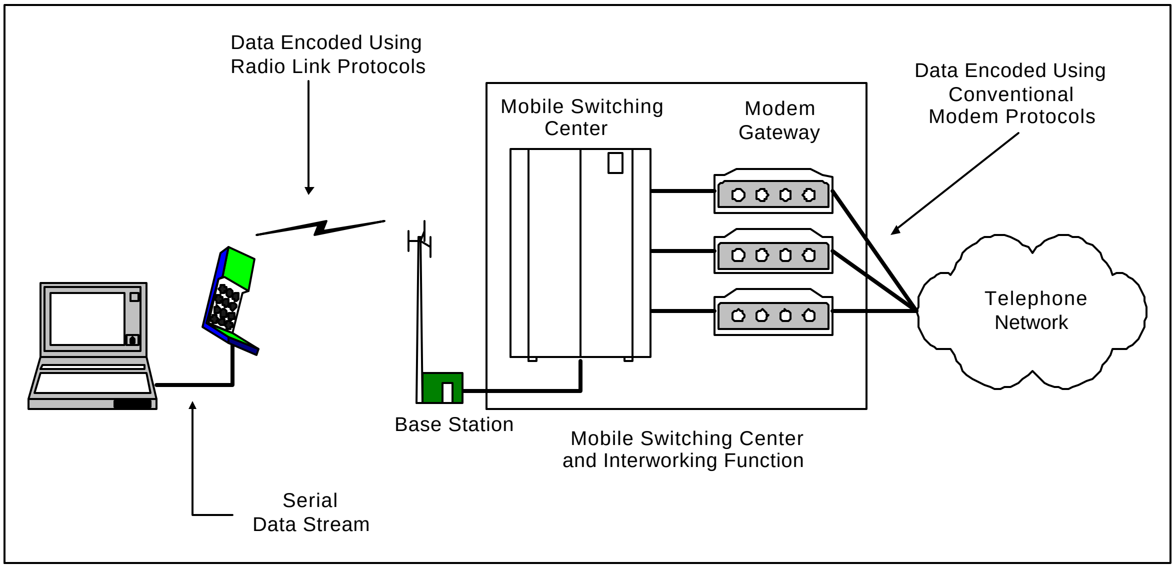


Figure 3: Circuit-Switched Connection via a Modem Interworking Function

Because circuit-switched connections involve dedicated circuits, a connection can take some time to establish. For instance, a modem connection might have a setup time of 10 to 40 seconds depending on modem protocols, compatibility of modems and other factors. Charges for circuit-switched connections are based on the duration of the connection as well as the distance between calling parties. Any modem-based communications application, based on TCP/IP communications protocols or otherwise, can be used over circuit-switched cellular connections, though customers must consider throughput and connection costs.

An alternative form of circuit-switched data for cellular systems is where the data call is switched into a packet infrastructure. This is similar to when users dial their ISP with a wireline modem. See Figure 4.

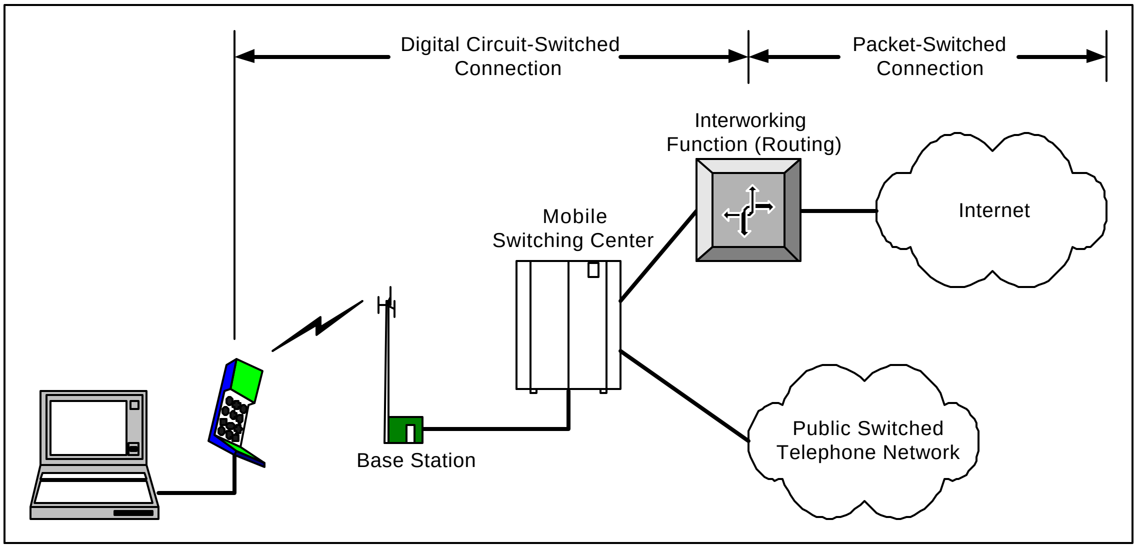


Figure 4: Circuit-Switched Connection to a Packet Infrastructure

The advantage of this approach is that the connection is relatively quick (typically less than five seconds), since no analog modem protocols are engaged. However, the biggest disadvantage is that the connection consumes minutes of use even when the user has no data to send or receive. Internet access for CDMA networks is currently based on this approach, e.g., wireless Web services for Sprint PCS and Verizon networks.

Circuit-switched data options are available for all three digital cellular technologies (GSM, CDMA and TDMA), though exact service offerings can vary depending on the technology and the operator.

Packet-Switched Data

In contrast to circuit-switched connections, packet-switched connections do not use a dedicated circuit between two end points. Rather, packet-switched connections allow multiple users access to multiple locations across a network simultaneously. Packets (packages of data) are sent from source to destination using the quickest route available. Ethernet, GPRS and CDPD are all good examples of packet-switched networks.

Because each packet contains a source and destination address, packets that make up a single transaction can be sent along different routes through the network. A packet from one user might immediately follow a packet from another user. Although packets theoretically can be of any size, typical packet sizes range from 100 to 1500 bytes. See Figure 5.

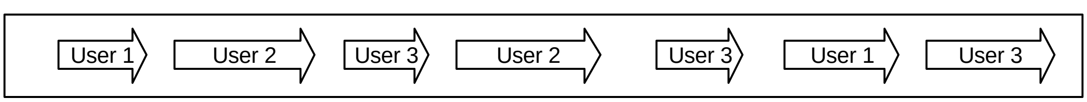


Figure 5: Packets from Multiple Users Traversing a Communications Channel

Transmitting information in packets can result in vastly increased efficiency and reduced costs to users. And because packet-switched networks generally interconnect with Public Data Networks (PDNs), such as the Internet, or directly to private intranets, a variety of new communication services is available to users.

Charges for packet-switched network services can be based on the amount of data communicated—the length of time over which communications occur is immaterial. A computing device could have an open connection to the network for an entire day, and charges would be incurred only for the data transmitted. Alternatively, carriers can offer flat-rate pricing.

Because packet-switched networks offer rapid connections, they are particularly well suited for applications such as AT&T Wireless PocketNet service, transaction-based applications, and transmissions involving short, "bursty" messages. Messaging, credit card authorization, database querying, dispatching and Web access are other good examples of packet-switched applications. With higher-speed technologies like GPRS, EDGE and UMTS, more demanding office-productivity applications and multimedia applications also become feasible.

Unlike circuit-switched data connections that involve the mobile switching center, packet-switched data services tend to involve infrastructure that is relatively independent of the voice-based infrastructure. See Figure 6.

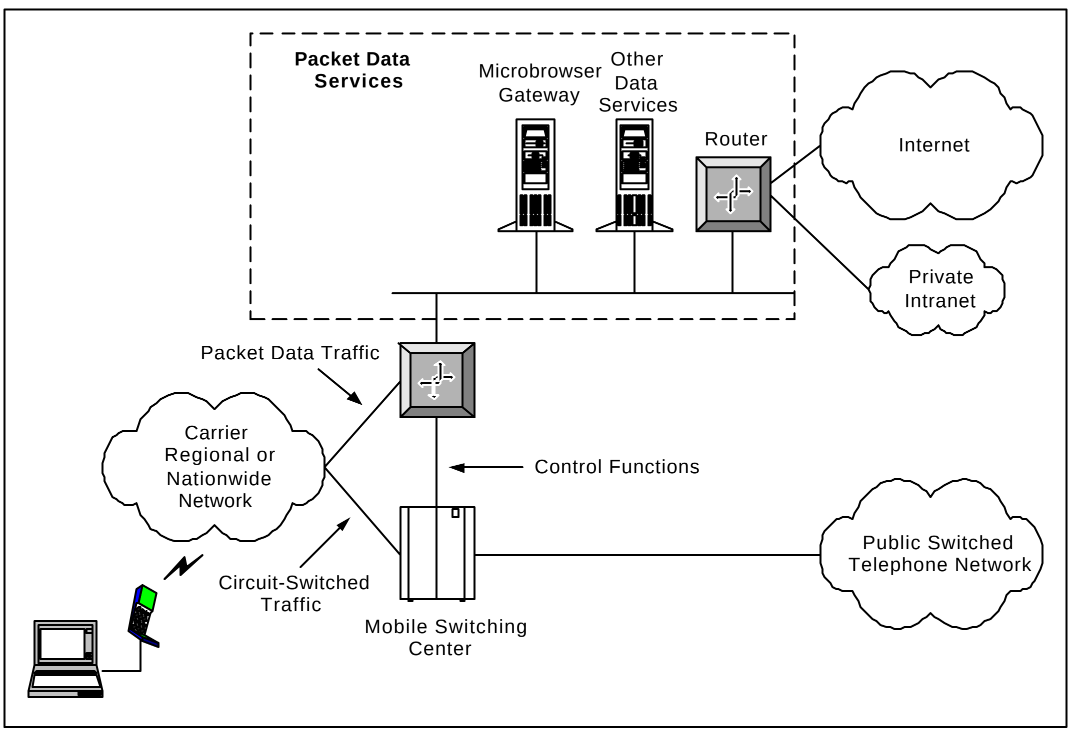


Figure 6: Separate Infrastructures for Voice and Packet-Data Services

Customer Devices for Packet-Data Networks

Typical customer devices will consist of either data-capable mobile telephones or modems dedicated for data functions. Other possibilities include modules or components that are integrated directly into other equipment, such as point-of-sale terminals.

In the case of data-capable mobile telephones, customers can choose either of these options:

- Take advantage of microbrowsers built directly into the phones (based on protocols such as the Wireless Application Protocol [WAP]).
- Use the phone as a modem, and connect the modem to a separate computing device, such as a notebook or handheld computer.

In addition, an increasing number of handheld computers will be available with either an integrated wireless capability or wireless modem modules. Figure 7 shows various possibilities. The types of devices and options for customers will only expand with time.

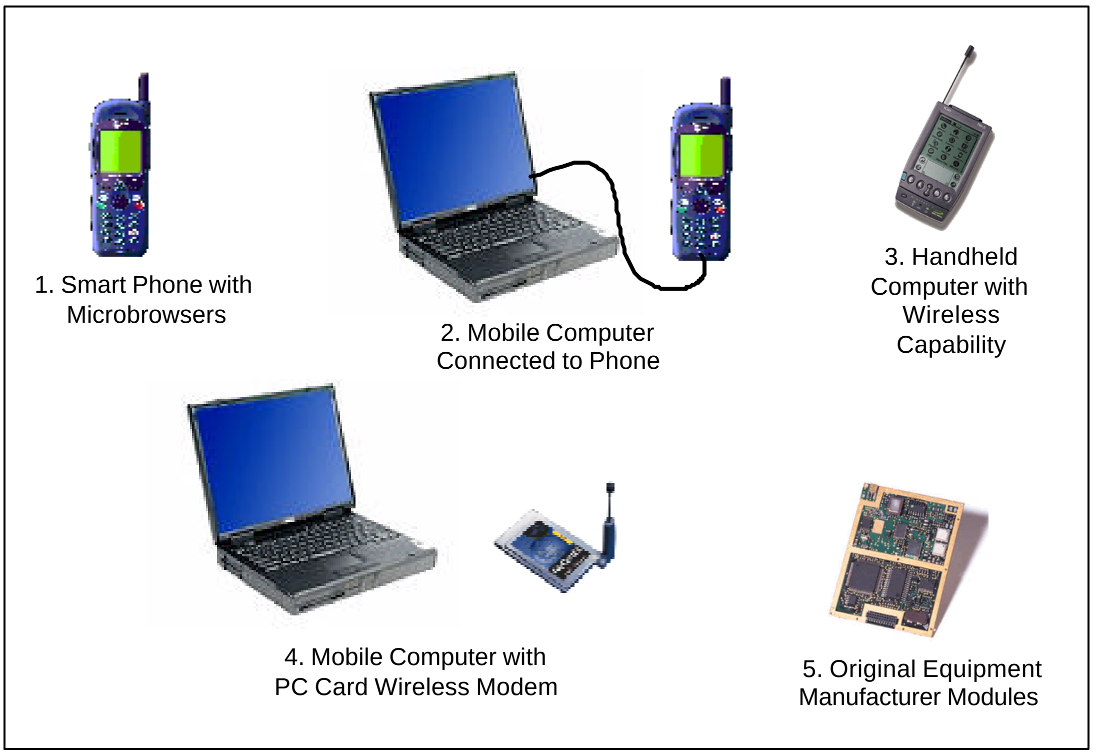


Figure 7: Variety of Customer Devices for Cellular Data

GSM and GPRS

GSM is a cellular standard originally developed by the European Telecommunications Standards Institute (http://www.etsi.org) and now maintained by the 3rd Generation Partnership Project (http://www.3gpp.org) and promoted by the GSM Association (http://www.gsmworld.com). GSM is used throughout Europe, in most Asian countries and in the U.S., where the largest carriers to adopt GSM are AT&T Wireless, Cingular and VoiceStream.

Like TIA/EIA-136, GSM is a TDMA technology. Voice services for TIA/EIA-136 and GSM networks are almost identical from a user perspective, though technical implementations differ. GSM divides 200-KHz radio channels into eight successive time slots, allowing eight users to use the radio channel simultaneously. See Figure 8. In contrast, TIA/EIA-136 networks use 30-KHz radio channels each with three time slots.

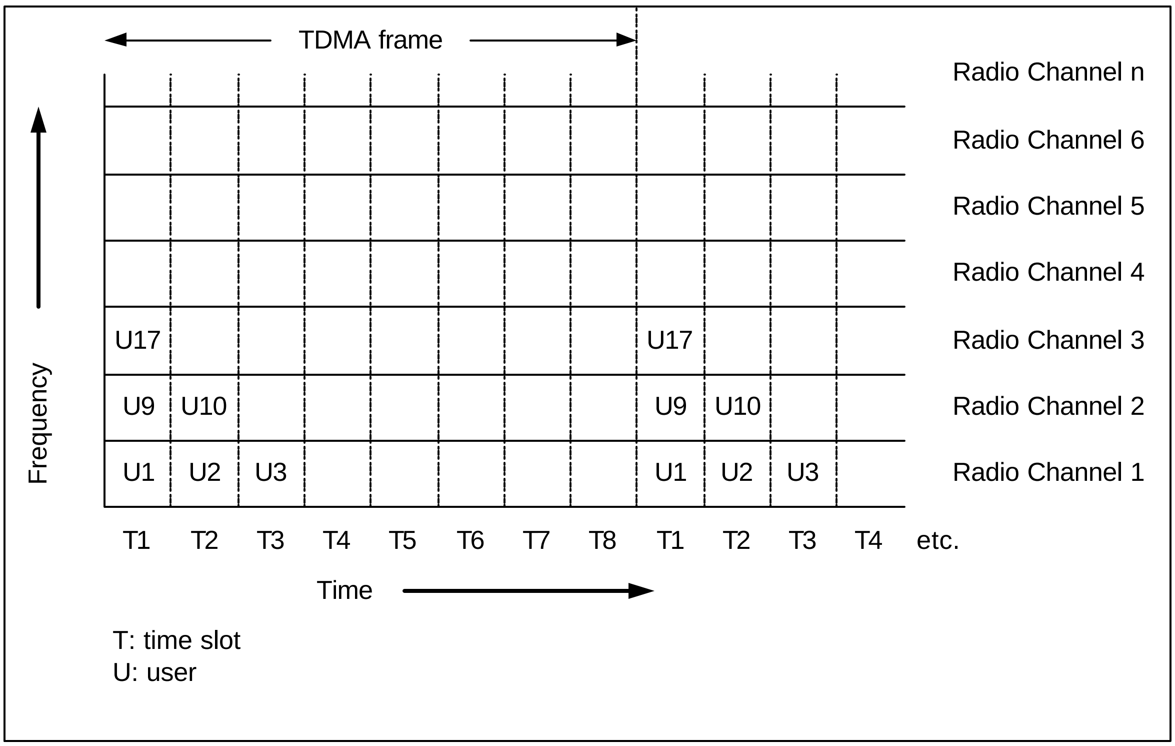


Figure 8: TDMA Radio Channels and Time Slots

GSM networks provide a two-way SMS capability. They also provide circuit-switched data service with about 14 Kbps of throughput. Data devices include data-capable mobile telephones or PC card format modems. Due to the many advantages of packet-switched data over circuit-switched data, AW included GPRS packet-data service in its GSM network.

High-Speed Circuit-Switched Data (HSCSD) is a data service that combines two to four time slots to yield download speeds as high as 56 Kbps. See Figure 9. However, few GSM operators have deployed this service.

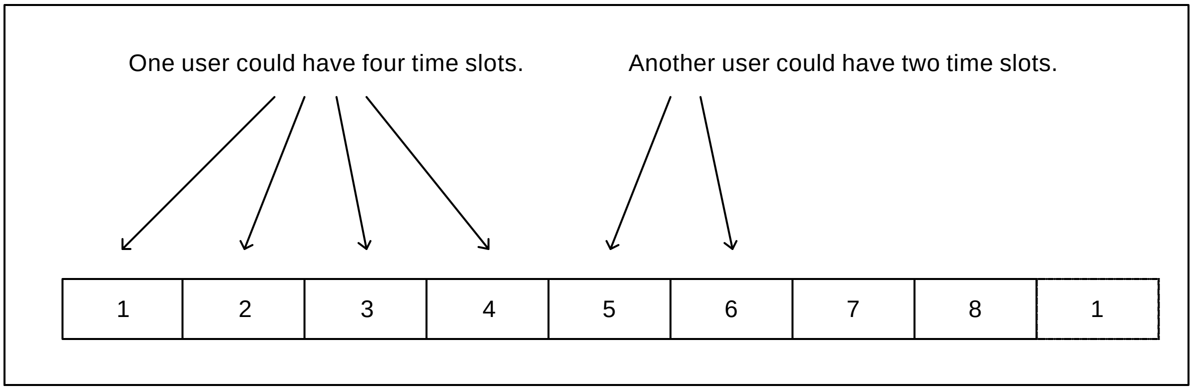


Figure 9: Combining Time Slots for Faster Speeds

GSM operators, including AW, are deploying a service called General Packet Radio Service (GPRS). GPRS is similar to CDPD in the type of service it offers customers, with the principal difference being significantly faster data throughput. GPRS, which is considered a 2.5G service, offers packet-based IP communications up to a theoretical maximum rate of 160 Kbps.

Actual data rates, however, depend on how the service is deployed and the types of devices that customers use. Exact throughput is determined by the number of time slots a device can support, which is typically two or four time slots for downloads and one time slot for uploads. At about 10 Kbps of actual user throughput per slot, this translates to 20 Kbps to 40 Kbps for downloads and 10 Kbps for uploads. Higher-speed devices using more than four time slots are possible, but not practical. Note that sometimes the press reports throughput per time slot at 14 Kbps, but this figure includes protocol overhead and is not the throughput available to users.

Another factor that affects data throughput is how many slots the carriers assign for GPRS service. If, for example, only four time slots are available for GPRS in a service area, then two users with four-slot devices wishing to use the service at exactly the same time would have to share the available time slots. This would effectively halve their throughput.

Customers should also realize that most data sessions do not involve continuous data transmission. Due to the packet-switching nature of the service, one user may be transmitting or receiving while another user is viewing the information he or she has just downloaded. This statistical sharing of the radio channel is extremely efficient compared to circuit-switched data service, where each user consumes the channel whether they are active or idle.

To increase performance, AW has deployed two different compression technologies. The first is V.42 bis, a link layer compression technology commonly used in wireline modem communications. Users have the option to enable this compression in their GPRS modems for applications that do not already compress data. The second compression technology is specifically for Web-based HTML (hypertext markup language) applications. Table 2 shows the types of performance users can expect with GPRS.

Time Slots for Downloads	User Throughput	User Throughput with Compression Enabled
1	10 Kbps	Up to 40 Kbps
2	20 Kbps	Up to 80 Kbps
4	40 Kbps	Up to 160 Kbps

Table 2: User Throughput Based on Time Slots and Compression

The architecture of GPRS, as show in Figure 10, employs two key architectural nodes: the Serving GPRS Support Node (SGSN) and the Gateway GPRS Support Node (GGSN).

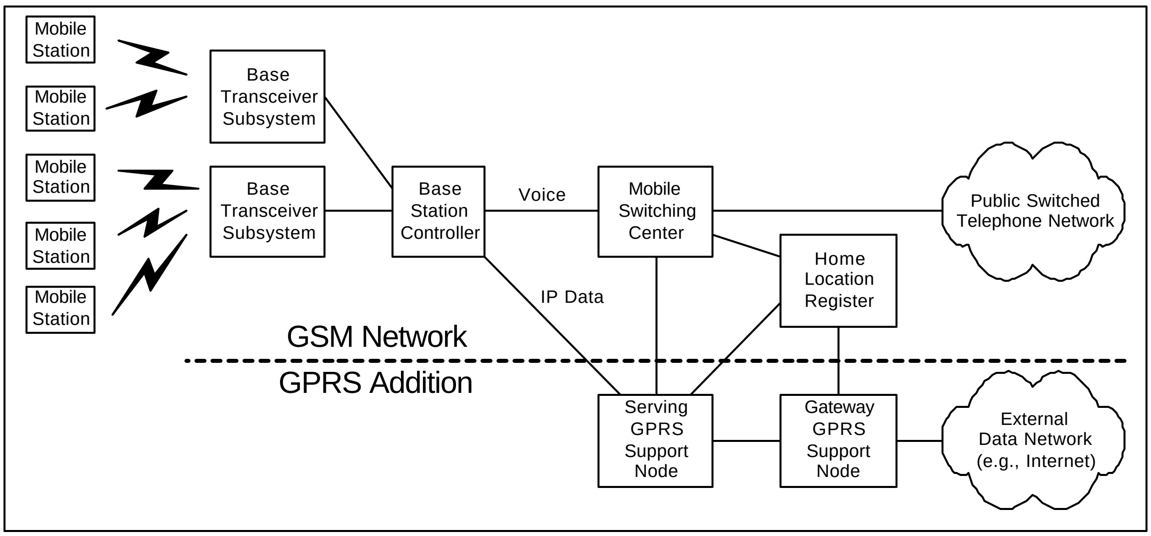


Figure 10: GPRS Architecture

The SGSN keeps track of the location of the mobile station, forwards user data from the mobile station to the GGSN, and sends data to the mobile station that originates from external networks like the Internet. The Home Location Register (HLR) contains user account information. The GGSN is the gateway between the GPRS network and other networks like the Internet.

From a functional perspective, GPRS is very similar to AT&T Wireless IP service. Similarities include:

1. The technology is packet based (uses airlink only when transmitting data).
2. The mobile station has an IP address (dynamic for GPRS, fixed for wireless IP).
3. The networks support communication with the Internet as well as private intranets through private connections.

In addition, GPRS will offer users the following features:

- Global coverage, with nearly every country in the world offering GPRS service
- Service that is consistent with the current CDPD-based wireless IP service, thus allowing immediate and easy migration of existing wireless applications. In addition, its faster speed will enable office-productivity applications and some multimedia applications.
- High data transmission rates of up to 40 Kbps
- A wide variety of devices, including data-capable mobile telephones, PC card modems for notebook computers, modems that can be used in personal digital assistants, messaging devices (e.g., RIM pagers) and OEM components
- The ability to suspend data sessions to accept or initiate voice calls. It is also possible to have devices that handle voice and data simultaneously, though these are not expected initially.
- Strong security features, including authentication and airlink encryption
- Support for Subscriber Identity Module (SIM) cards

Carriers will have the option of enhancing GPRS networks in the future using a new radio interface called EDGE (Enhanced Data Rates for GSM Evaluation). EDGE is a sophisticated radio technology that can dynamically adapt modulation and data encoding methods to achieve the maximum possible throughput based on current signal strength and interference conditions. EDGE networks can deliver effective data throughput of up to 120 Kbps (over 384 Kbps peak), and they are expected to be available beginning in 2002.

Beyond GPRS and EDGE is the third-generation technology called UMTS (Universal Mobile Telecommunications System), which employs a wideband CDMA airlink. Though based on similar radio principles as existing CDMA networks, UMTS is different from CDMA2000. UMTS, which will offer peak throughput rates of 2 Mbps, is the best choice for AW for many reasons. AW can install UMTS in its existing cell sites. UMTS will offer roaming options worldwide and is interoperable with GSM networks. Finally, UMTS is likely to become the dominant global cellular standard.

The 3rd Generation Partnership Project is developing the UMTS set of standards so that the same core network will support multiple radio access networks, whether GPRS, EDGE or the UMTS radio interface. See Figure 11. The net result will allow customers to be able to roam between GPRS, EDGE and UMTS networks.

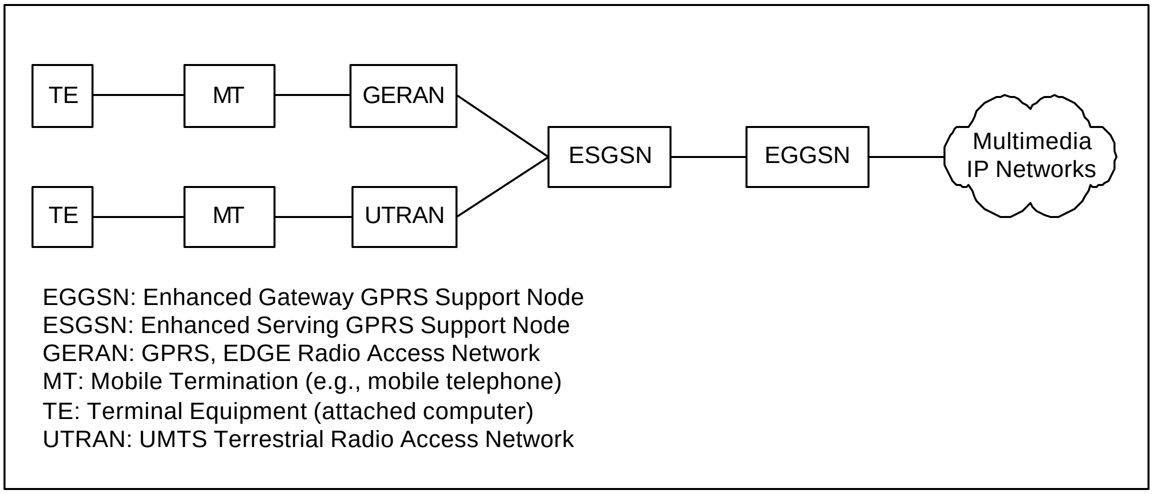
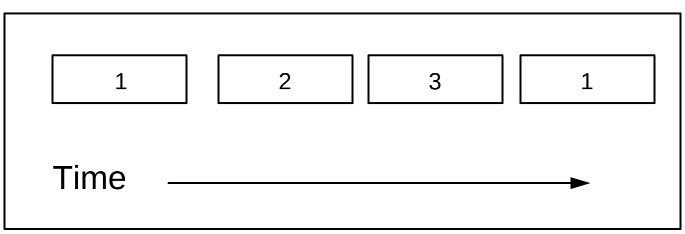


Figure 11: Common Core Network for both UMTS and EDGE Access Networks

For more details about GPRS, refer to Appendix C: AT&T Wireless GPRS Network.

TDMA (TIA/EIA-136) Networks

TIA/EIA-136, commonly referred to as TDMA (Time Division Multiple Access), is a U.S. standard developed by the Telecommunications Industry Association (http://www.tiaonline.org) that specifies the digital cellular technology used by AT&T Wireless and Cingular Wireless in the United States, as well as by a large number of other operators worldwide. It is a Time Division Multiple Access (TDMA) technology that divides 30-KHz radio channels into three successive time slots, allowing three users to use the channel simultaneously. This is a dramatic improvement over analog cellular systems, where each radio channel is dedicated to a single user. See Figure 12.



With TDMA, mobiles transmit successively using time intervals.

Figure 12: TDMA Time Slots

For messaging, TIA/EIA-136 offers SMS, with each cell phone containing an Internet-accessible e-mail address. For example, a cell phone with the number of 425-555-1111 would have the e-mail address of 4255551111@mobile.att.net. AW has upgraded its SMS to support two-way communications, allowing users to send messages from their cell phones.

Circuit data services for TDMA are defined in the standard TIA/EIA-360-350-A, which offers a data rate of 9.6 Kbps using a single time slot, or as high as 28.8 Kbps using all three time slots in a radio channel. User devices can include data-capable cell phones that have a microbrowser or that can be used as a modem for an attached computer (e.g., laptop or handheld). Data-only modems can also be available in PC card format. Some TDMA operators are offering service using this technology, but AW is instead emphasizing its CDPD and GPRS technologies.

Standards organizations have defined a packet data service for TIA/EIA-136 networks called Enhanced GPRS-136 (EGPRS-136), which uses the same EDGE radio interface designed for GPRS networks. However, AW intends to provide its GPRS service over a new GSM network rather than upgrading its TDMA network.

CDMA (TIA/EIA-95) Networks

TIA/EIA-95A is a U.S. standard that specifies digital cellular networks based on a technology called Code Division Multiple Access (CDMA). The largest operators for CDMA in the U.S. are Verizon and Sprint PCS. Operators have also deployed CDMA networks overseas, with Korea and Japan being the largest markets. There are no CDMA networks in Europe. The successor to TIA/EIA-95A is CDMA2000, a standard controlled by an international organization called the 3rd Generation Partnership Project 2 (3GPP2).

CDMA networks differ substantially from TDMA networks in that the radio channels are much wider, 1.25 MHz versus 30 KHz as used in TIA/EIA-136 networks or 200 KHz in GSM networks. In CDMA, all users of the radio channel communicate simultaneously, rather than in time slots. The signals are combined with pseudorandom signals, "codes," that allow the receiving system (which knows the code) to extract the original signal. See Figure 13.

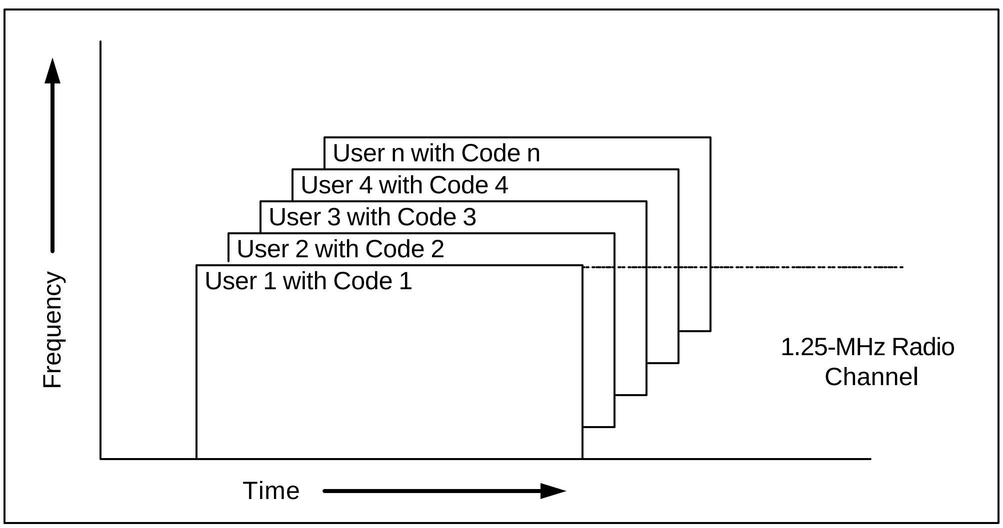


Figure 13: Users Share Channel Using Codes

CDMA networks offer a two-way SMS capability. In addition, operators in the U.S. offer circuit-switched data service of up to 13 Kbps. This service is specified in the TIA/EIA 707 standard. CMDA operators are providing both a modem interworking function and circuit-switched connections to the Internet via a service called QuickNet Connect. Both of these types of services are described in the prior section, "Circuit-Switched Data." QuickNet Connect is the transport for current wireless Web services offered by Sprint PCS and Verizon.

Though a packet-data capability was defined for current TIA/EIA-95A networks, operators have chosen to deploy packet-data capability with newer versions of CDMA technology, such as TIA/EIA-95B and CDMA2000. TIA/EIA-95B is a version of CDMA that provides higher-speed packet data at rates up to 64 Kbps. CDMA2000 1XRTT (one carrier radio transmission technology) will offer packet data up to a theoretical maximum rate of 153 Kbps, though actual user rates will depend on a variety of factors and are more likely to be in the 40 Kbps to 60 Kbps range, depending on devices and service offerings. Carriers can deploy CDMA2000 1XRTT technology in the existing spectrum and are expected to do so in 2002.

Another type of data service planned for CDMA is called CDMA2000 1XEVDO (where EV stands for evolution and DO for data only). 1XEV is a technology that requires an operator to dedicate a 1.25-MHz radio channel to data only. 1XEV promises actual user data rates of about 600 Kbps under optimal conditions. Deployment is not expected until 2003 or 2004.

Another version of CDMA2000, called 3XRTT, will boost data rates to 384 Kbps outdoors and to 2 Mbps indoors. CDMA2000 3XRTT, however, requires 5-MHz radio channels and is not expected to be deployed in the U.S. until new 3G spectrum becomes available. Carriers may deploy 1XEV instead.

The CDMA2000 architecture is shown in Figure 14, and is the same for the 1XRTT, 1XEV and 3XRTT radio interfaces. The core network element is the Packet Data Serving Node (PDSN). CDMA2000 is fully based on TCP/IP protocols, and it uses either a simple IP model with an IP address dynamically assigned to a mobile station, or a mobile IP model where mobile stations can keep the same IP address as they roam between CDMA2000 networks and other networks. Mobile IP standards are still in development, and it is likely that initial services will be based on the simple IP approach.

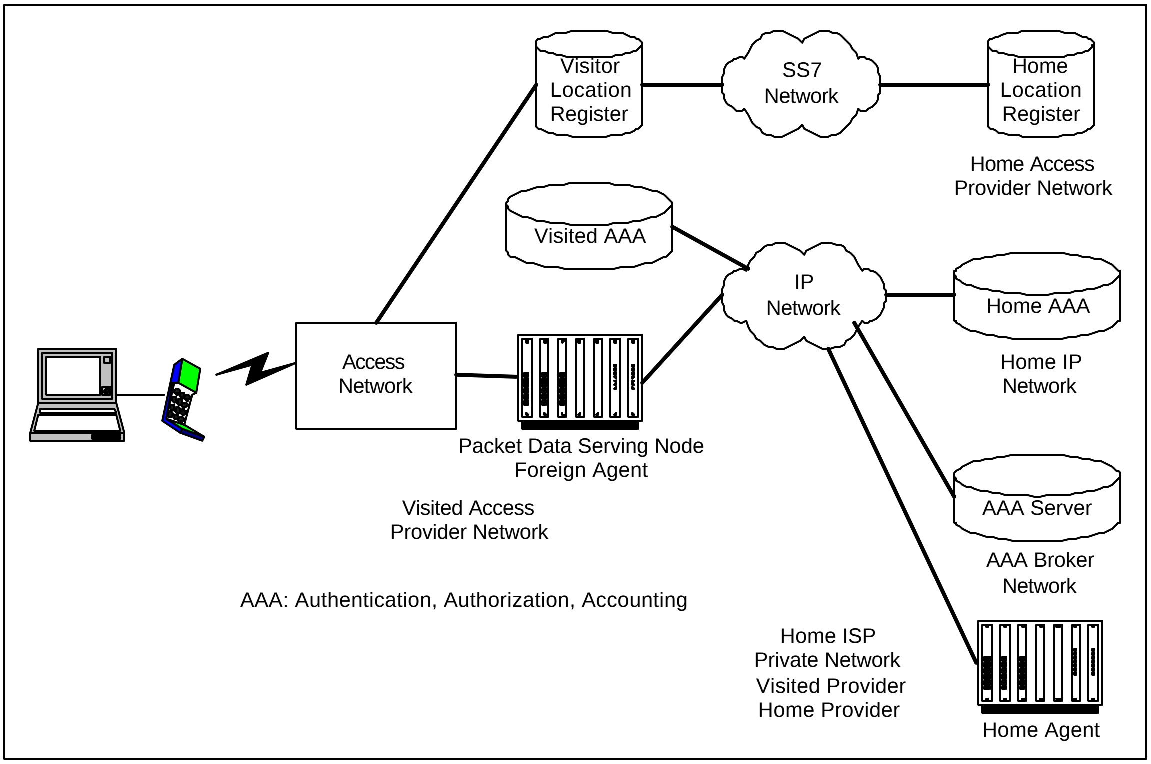


Figure 14: CDMA2000 Architecture

Analog Cellular

Communicating data over analog cellular connections is feasible, but it should only be considered in geographic areas where the AT&T Wireless IP network or AW GPRS network are not available. Communication is not as reliable as with CDPD- or GPRS-based service, and usage is more complicated. Most customers using this approach do so for specialized applications. With the right equipment, data rates can vary from 1.2 Kbps to 14.4 Kbps depending on signal strength and interference, with 9.6 Kbps being typical.

To achieve reliable modem connections, customers need to:

- Use a modem that supports cellular protocols like Enhanced Throughput Cellular (ETC). Protocols such as ETC have higher degrees of error correction than conventional modem error protocols like V.42.
- Connect the modem to a compatible mobile telephone. Modems with cellular protocols can only connect to certain cellular telephones. A special cable is also required to interconnect the two. Some modem vendors, such as Sierra Wireless, have integrated units that combine the modem and the radio transceiver into a PC card or external unit.

- Communicate with a landline modem that supports the same cellular protocol as the mobile unit. Most landline modems do not support the cellular protocols, so customers must purchase the appropriate landline equipment.

Figure 15 shows these elements.

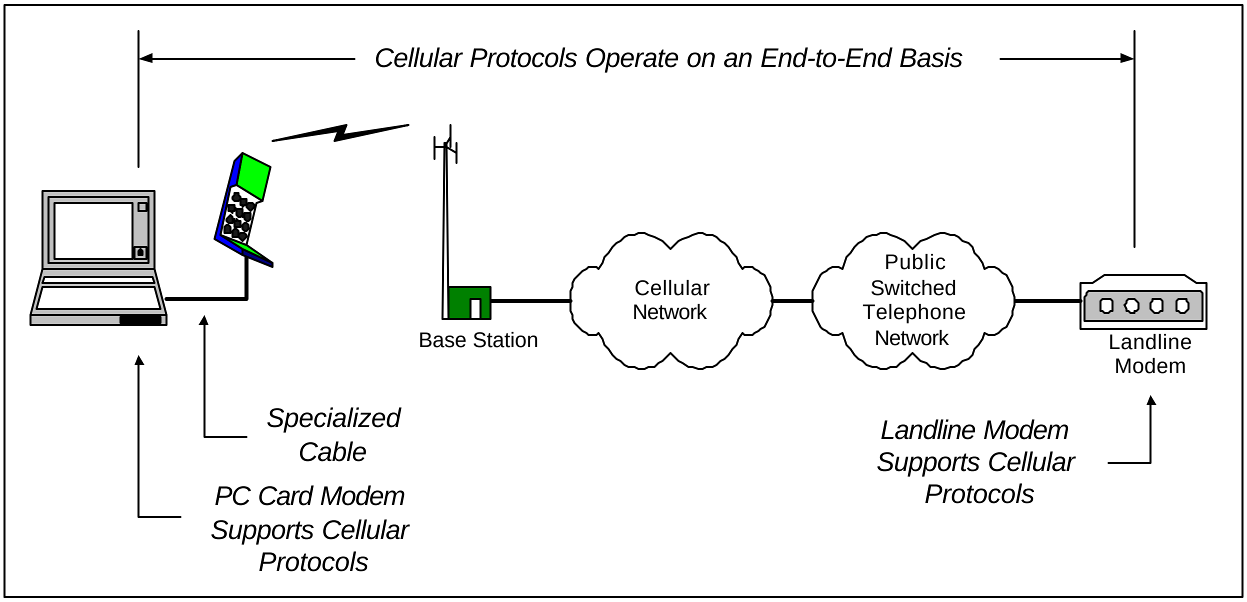


Figure 15: Elements in Data Communications over Analog Networks

Making the necessary arrangements to communicate data over analog cellular can be too complex for the average end-user customer, but this can be readily addressed by system integrators developing specialized applications.

Integrated Dispatch-Enhanced Network (iDEN)

iDEN is technology developed by Motorola and used by Nextel and the Southern Company in the U.S. and Telus Mobility in Canada. It belongs to a category of technology called Enhanced Specialized Mobile Radio (ESMR). ESMR is a digital enhancement for Specialized Mobile Radio (SMR). SMR systems are primarily used for dispatch applications, such as transportation services and support for field technicians. Unlike earlier dispatch systems based on private radio channels, SMR systems are public systems operated by companies that sell radio service. ESMR replaces SMR systems with all-new digital technology that is cellular in nature. ESMR networks also consolidate many smaller SMR systems into larger networks.

iDEN is essentially a cellular technology, reusing frequencies in a cellular fashion, using GSM protocols internally within the network, and providing voice services similar to cellular networks. Where it differs is that iDEN is a proprietary Motorola technology not under the control of any standards organization. Furthermore, it operates in the 806- to 821-MHz and 851- to 866-MHz bands, which are different frequencies than cellular or PCS bands. Finally, iDEN applications favor work groups (such as construction work crews) due to a voice feature that lets one person talk simultaneously to a predesignated group of people. Figure 16 shows the network architecture.

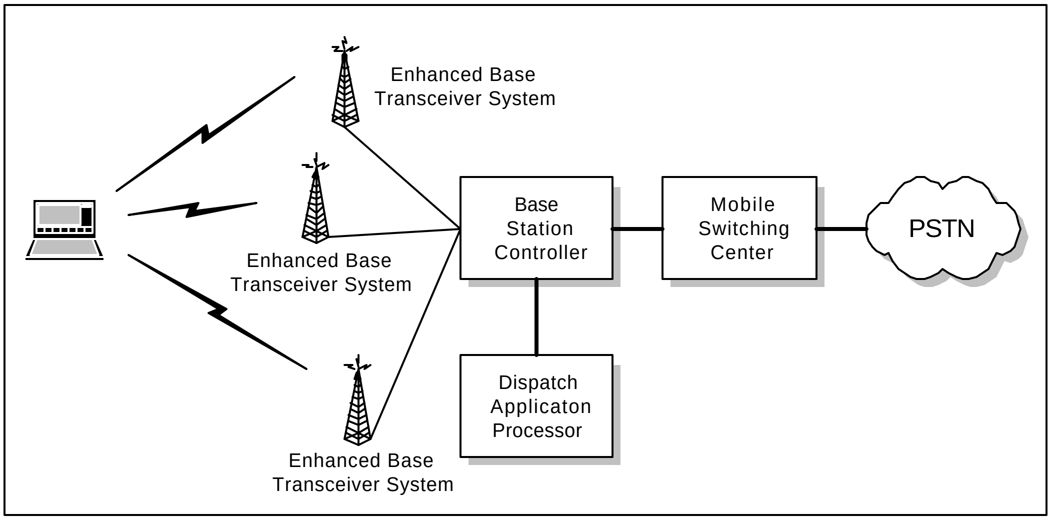


Figure 16: iDEN Architecture

The iDEN technology provides for a number of data services, including:

- Short message service (SMS)
- Microbrowsers based on the Wireless Application Protocol (WAP)
- Circuit-switched data to 9600 bps
- IP-based packet data to about 20 Kbps

Motorola is the principal manufacturer of handsets and modems for iDEN.

Noncellular Data Networks

In addition to the data services for cellular networks, there are a number of other wide-area wireless-data networks in operation. This section discusses these networks, and contrasts them with the AT&T Wireless IP network and the AW GPRS network. Further details on these networks are available in Appendix D: Noncellular Network Details, and in Appendix E: Wireless Data Comparison Tables.

There are two networks operating in the U.S. that have similarities to the AT&T Wireless IP network. One is the Cingular Interactive network and the other is the Motient network. Both networks are packet based, but neither uses IP as its networking protocol, which can complicate application development. Both networks offer good coverage throughout the U.S. and Canada. Both also offer similar customer devices: either modems for mobile computers or messaging devices such as the Inter@ctive™ Pager from Research in Motion. Most new customers are using these messaging devices instead of separate modems. The Palm™ VII integrates a modem for use with the Cingular Interactive network. For further details, including the types of applications supported, see the sections "Cingular Interactive" and "Motient Network."

Similar in some respects to these two packet networks are two-way paging networks. Key carriers include Arch Wireless, Metrocall, SkyTel and WebLink Wireless. Originally, paging networks could only transmit information; but with the addition of new network infrastructure, it is now possible for customers to purchase small messaging devices that can both receive and send messages. Due to the limited capacity of paging networks, however, message sizes are quite limited, with 500 characters a practical upper limit. Furthermore, message delays can approach minutes in duration when the networks are busy. Note that Motorola, the largest vendor of paging equipment, is not planning to advance its paging technology. For further details, see the section "Two-Way Paging Networks."

The Aerie Networks Ricochet™ is a packet network that supports IP communications as high as 128 Kbps under optimal conditions. Customer devices are either PC card modems or external modems that use a serial connection to a mobile computer. Though communication speeds are attractive, service today is limited to a small number of metropolitan areas. Furthermore, the network uses unlicensed radio bands, increasing the risk of interference from other users of the band, including wireless LANs and cordless telephones. For further details, see the section "Aerie Networks Ricochet."

Two service providers have deployed networks for telemetry applications. These networks are Aeris.net and Cellemetry. The primary application is for fixed systems needing to communicate only small amounts of information. Examples include vending machines needing refills or copiers needing toner. Both networks communicate short messages of up to 32 bits in analog cellular control channels. For further details, see the section "Telemetry Systems: Aeris.net and Cellemetry."

Appendix A: Summary of Cellular Data Services

Table 3 summarizes the current and forthcoming data services for the three major digital cellular technologies.

Network Technology	Service	Data Capability (Actual User Throughput)	Expected Deployment
TDMA (TIA/EIA-136)	Circuit-switched data based on the standard TIA/EIA-136-350	9.6 Kbps	Available from some carriers now, e.g., Cingular Wireless
	EDGE/EGPRS-136	IP communications to 384 Kbps	No planned deployment. TDMA carriers will instead deploy GSM/GPRS, EDGE and UMTS networks.
GSM	Circuit-switched data	13 Kbps	Available from many GSM carriers
	High-Speed Circuit-Switched Data (HSCSD)	26- to 52-Kbps service	Limited deployment
	General Packet Radio Service (GPRS)	IP communications with typical data rates of 20 Kbps to 40 Kbps	Widespread deployment in 2002
	Enhanced Data Rates for GSM Evolution (EDGE)	IP communications to 120 Kbps	Initial deployments in 2002
	UMTS	384 Kbps outdoors and 2 Mbps indoors. Uses wideband CDMA airlink with an enhanced GPRS infrastructure for data service.	Initial deployments in 2002
CDMA	Circuit-switched data	13 Kbps	Available now
	CDMA2000 1XRTT	IP communications, 40 to 60 Kbps	2002
	CDMA2000 1XEV	IP communications to 600 Kbps	2003 or 2004
	CDMA2000 3XRTT	IP communications to 384 Kbps outdoors and 2 Mbps indoors	No current deployment plans
iDEN	Packet-switched data	19.2 Kbps	Deployed.-

Table 3: Summary of Cellular Data Services, Excluding SMS

Appendix B: AT&T Wireless IP Network (CDPD)

The AT&T Wireless IP network is based on a wide-area network architecture composed of systems and a well-defined set of communications protocols using a technology called Cellular Digital Packet Data. CDPD was initially developed by a consortium of cellular operators; it is now an official standard (TIA/EIA-732). Together, these systems and protocols make the transmission of packet data across cellular networks possible. The wireless IP network does not stand alone; it is designed to operate as an extension of existing Internet protocol (IP) data communication networks, such as the Internet and private intranets. See Figure 17.

While sharing base station towers, radio channels, and radio equipment with cellular networks, it employs an infrastructure that is relatively independent of the rest of the AT&T cellular network.

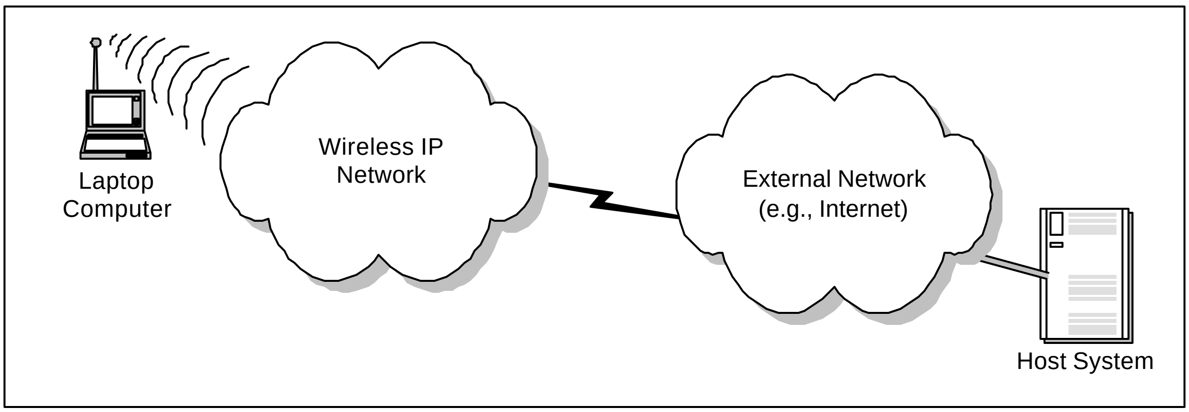


Figure 17: CDPD as an Extension of Other Networks

Usage

Wireless IP is an ideal solution for transaction-based communications and for transmissions involving short, "bursty" messages. Some ideal applications include the AT&T Wireless PocketNet service, e-mail, database querying, dispatch services, mobile traffic information, credit card verification and emergency services. Other applications suited for wireless IP are those for which sessions (or log-in time) may be lengthy, but where communication is sporadic. With wireless IP, the user is charged only for the data communicated—not for connect time. Flat-rate plans are also available.

Architecture and Data Capabilities

Users of wireless IP obtain 19.2 Kbps of raw throughput, including protocol overhead, and 10 Kbps to 13 Kbps of actual throughput. Latencies (delays) across the network are typically quite low, measuring in the hundreds of milliseconds.

As illustrated in Figure 18, customers access the wireless IP network using an AT&T Wireless PocketNet service-compatible phone, laptop computer or other computing device equipped with a wireless modem. Each wireless IP modem has a fixed IP address that is assigned by AW. The modem transmits packets on radio frequency channels that are separate from those used for cellular voice transmissions. The data is received by a Mobile Data Base Station (MDBS), which manages data transmissions on cellular channels at its cell site. The MDBS forwards the data to the Mobile Data Intermediate System (MD-IS), a core routing and network management entity in the wireless IP network. The MD-IS routes packets through the wireless IP backbone network to an interconnecting network (e.g., private network or Internet) for delivery to a fixed-end system.

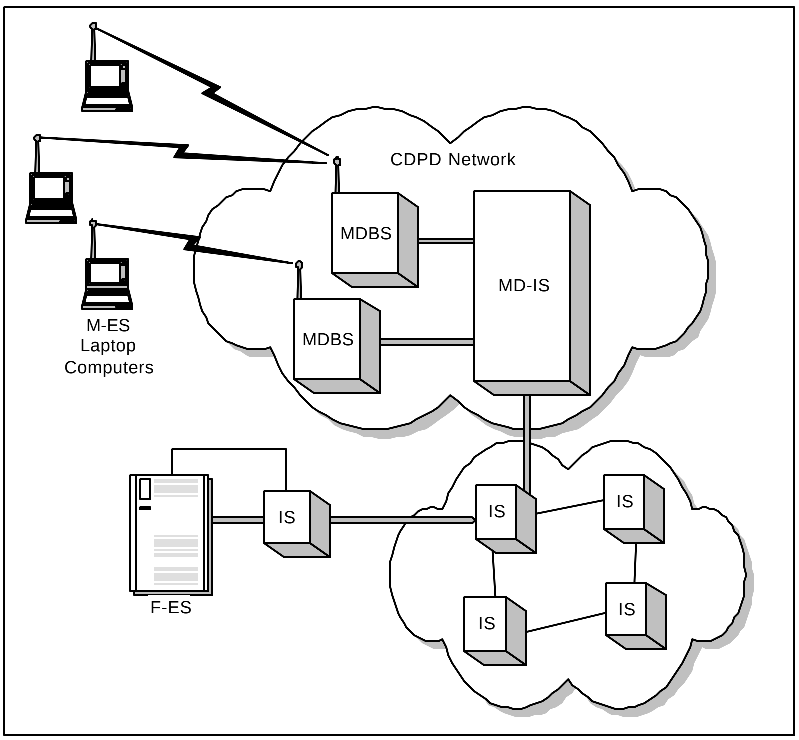


Figure 18: Primary Elements of the Wireless IP Network

Since the wireless IP network uses standard IP networking protocols, interconnections between the wireless IP network and customer networks are greatly simplified (as compared to wireless networks that do not use IP networking).

Connections to Other Networks

Most corporate customers connect their networks using Frame Relay circuits from public carriers. Since the wireless IP network also has a connection to the Internet, an increasing number of customers are using the Internet for connecting their systems. Figure 19 shows how the wireless IP network connects to other networks.

For more information about these fixed-end connections, refer to the white paper "Connecting Fixed-End Systems to the AT&T Wireless IP Network."

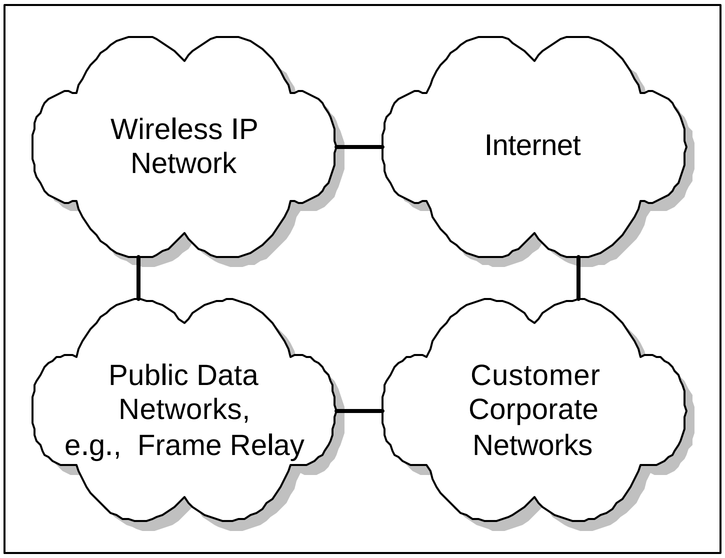


Figure 19: Wireless IP Connections to Other Networks

The cellular operators that provide wireless IP service have interconnected their networks. wireless IP allows mobile computers and AT&T Wireless PocketNet service-compatible phones to be used anywhere within the network, even outside the mobile's "home" operating area.

Communications Protocols

IP has emerged in recent years as the wide-area networking protocol of choice. By supporting IP, the AT&T Wireless IP network allows developers to use existing network applications and tools when designing for the wireless environment.

Given the broad support for IP, application developers who develop efficient and optimized wireless applications using IP will be rewarded by multiple wireless transport opportunities. The AT&T Wireless IP network offers the best choice of wireless networks today for IP communications. When other networks, such as GPRS, offer particular advantages, the application can be used on that network as well, thus minimizing the risk of obsolescence.

Industry-standard protocols SLIP (Serial Line Internet Protocol) or PPP (Point-to-Point Protocol) are typically used between the mobile computer and the wireless modem, as shown in Figure 20.

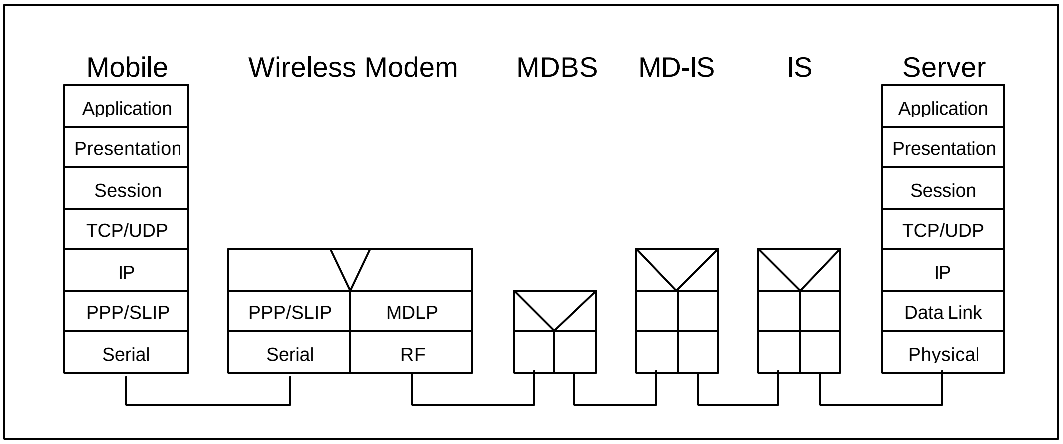


Figure 20: Protocols Used with CDPD

Wireless IP provides security by authenticating the mobile device and by encrypting the airlink.

Modems and Platforms

A number of companies sell wireless IP modems and mobile telephones for AT&T Wireless PocketNet service. A broad selection of form factors is available, including rugged external devices for industrial applications, components for telemetry-based applications, and small, handheld units for the mobile professional, including PC card formats. More companies are offering modems for wireless IP than for any other type of wireless data network, with seven vendors currently offering some twenty-five different products.

Application Development

Wireless IP provides an optimal environment for application development. Customers can easily format Web-based content for AT&T Wireless PocketNet service. In addition, a large number of IP-based applications can be used immediately over the wireless IP network. For existing applications, customers should consider some optimization because of the nature of the wireless connection. In addition, a variety of providers provide middleware tools to facilitate application development.

Appendix C: AT&T Wireless GPRS Network

This white paper introduced GPRS above in the section "GSM and GPRS." This section provides more in-depth information about GPRS technology as well as the AW GPRS network. GPRS consists of communication protocols and an architecture that provide a packet-data capability for GSM networks. GPRS can provide wireless access to networks that are based on either IP protocols or X.25 protocols, though most operators, including AW, will concentrate on IP. GPRS is controlled by a set of GSM protocols maintained by the 3rd Generation Partnership Project. Just like AT&T Wireless IP service that uses CDPD, the AW GPRS service is designed to operate as an extension of existing IP-based data communication networks, such as the Internet and private intranets. This means users with a GPRS device (e.g., modem or data-capable cell phone) can maintain their Internet connections or connections to their private networks when they are mobile.

Usage

Compared to CDPD, GPRS supports higher speeds and has a greater capacity for data. As a result, GPRS can also support applications like office productivity applications, some multimedia applications and general-purpose Web access. But, similar to CDPD technology, GPRS is also an ideal solution for transaction-based communications and for transmissions of short, "bursty" messages. Therefore, GPRS is an ideal communications channel for mobile telephones with microbrowsers, e-mail, database querying, dispatch services, credit card verification and emergency services. GPRS billing will be based on the volume of data communicated.

Architecture and Data Capabilities

Users of GPRS can obtain throughput four times higher than with CDPD technology. User throughput ranges from 10 Kbps to 40 Kbps, depending on the type of user device, the number of other active users in the cell site and the user application. Throughput is discussed in more detail above in the section ""GSM and GPRS." Latencies across the network are typically quite low, measuring in the hundreds of milliseconds.

Figure 10 above and Figure 21 below show the architecture of GPRS. The key elements of a GPRS network are the Serving GPRS Support Node (SGSN), Gateway GPRS Support Node (GGSN), Home Location Register (HLR), and Border Gateway (BG).

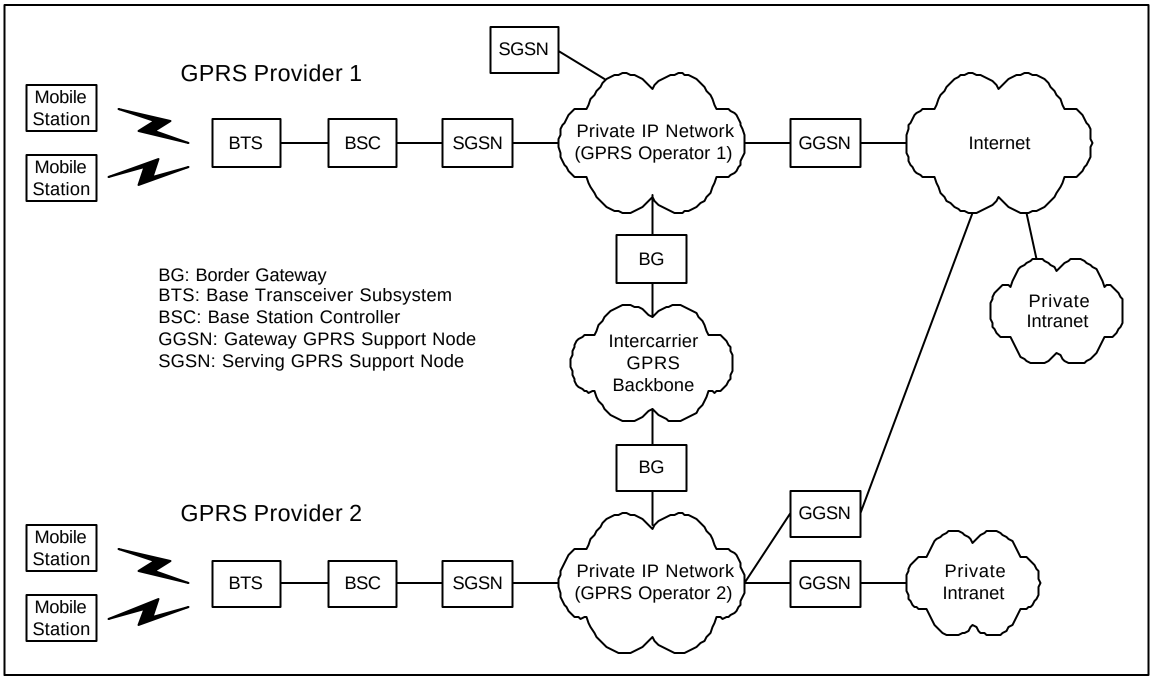


Figure 21: GPRS Architecture with Multiple GPRS Networks

The SGSN routes packets to and from mobile stations in a particular geographical area. For all user data packets that originate from the mobile station, the SGSN determines which Gateway GPRS Support Node (GGSN) to send them to and forwards them accordingly. It also keeps track of the location of mobile stations, is involved in the authentication of mobile stations, and encrypts communications to the mobile station (MS). The SGSN communicates with the HLR to obtain user account information and to find out which GGSN to connect with for a particular data connection.

The GGSN is the gateway between the GPRS network and other networks like the Internet. The GGSN assigns dynamic IP addresses to mobile stations. These can be either private or public addresses. Private addresses require a translation at the GGSN from an internal private address to a public IP address. The advantage to the operator is that multiple private addresses can share one public IP address, which is necessary given the limited number of IP addresses available today. The GGSN can also support mobile stations that have static IP addresses, though the support of static IP addresses will be operator dependent.

The GGSN accepts packets (e.g., from the Internet) addressed for an MS and sends them using tunneling protocols to the SGSN, which then delivers the packets to the MS. The GGSN provides other functions like handling multicasting (where packets may be destined for multiple mobile stations) and tracking which SGSN is serving the MS. It also is involved in accounting functions, such as tracking a user's account activity. Together, the SGSN and GGSN perform the functions of the Mobile Data Intermediate System (MD-IS) in CDPD networks.

A user can have connections to more than one external network. For example, one connection may be for generic Internet access, but another might provide access to a private intranet. As part of initiating a data session, called a Packet Data Protocol (PDP) context, the MS specifies an Access Point Name (APN). The APN specifies the external network with which to communicate.

Connections to Other Networks

There are a number of important connection types between GPRS networks and other networks, as shown in Figure 21. One type is between GPRS operators, a connection that allows users from one network to be able to roam to another GPRS network. A second type is between the GPRS network and the Internet. A third type is between the GPRS network and private intranets.

GPRS operators interconnect their networks via an Intercarrier GPRS Backbone Network or GPRS Roaming Exchange, which are essentially private IP networks. The interface to the backbone network is called a Border Gateway, whose principal purpose is to provide security functions that allow only authorized traffic to pass through.

The connection of greatest interest to many users is between the GPRS network and the Internet, a function handled by the GGSN, whose functions are described in the previous section. The connection to the Internet provides customers with two powerful communication options: one is for accessing Internet sites, such as Web servers; the other is for communicating with their organizations that are also connected to the Internet. Generally, customers communicating via the Internet to their home organization employ virtual private network (VPN) technologies to secure the connection. Customers can either deploy their own VPN technology or use a managed Internet service available as an option from AW.

The final type of connection is a direct connection between the GPRS network and a private intranet. Such connections also employ a GGSN. The link between the GGSN and the customer network can be over a Frame Relay network, Asynchronous Transfer Mode (ATM) connection, leased-line connection or whatever connection the carrier chooses to support. AW offers customers private virtual connections (PVCs) over its Frame Relay network. Customers should realize that this direct connection costs more than using the Internet but offers enhanced security and better quality of service.

Communication Protocols

GPRS employs a number of communications protocols to provide its services. Some of these are standard networking protocols, while others are unique to GPRS. Understanding these protocols provides insight into how GPRS works, but is not necessary for using the service or for developing and deploying applications. From an applications perspective, GPRS simply provides wireless access to IP-based networks.

Working from the top downward, as shown in Figure 22, the user's IP datagrams are at the "network layer." Layers above the network layer, such as TCP, HTML, and application-layer protocols, do not need to be considered, as they simply constitute data carried within the user's IP data.

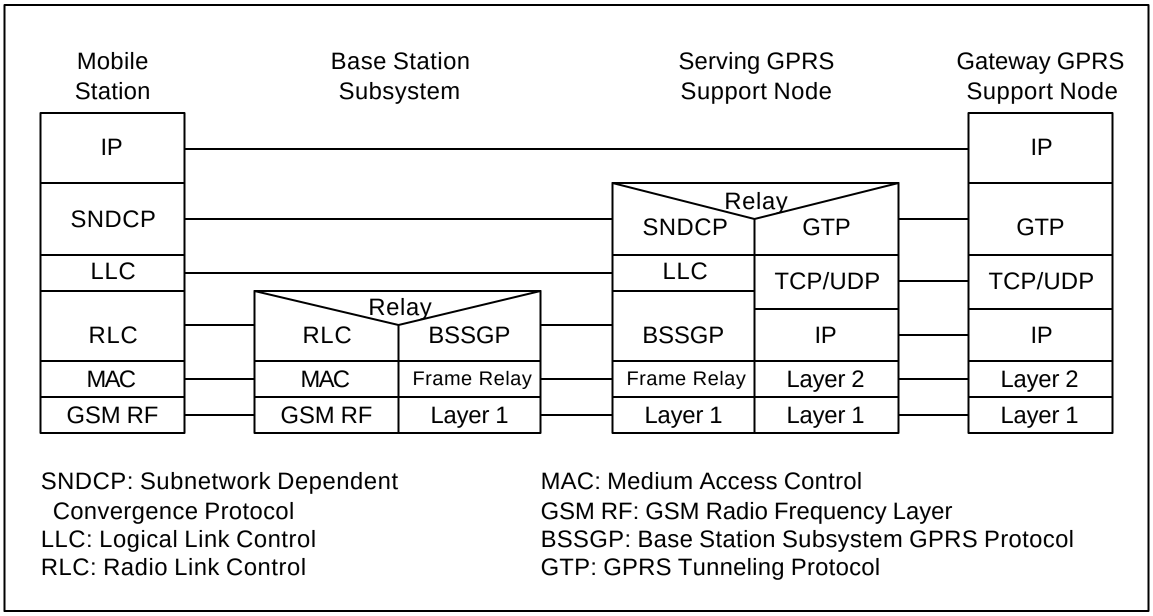


Figure 22: Protocols Used with GPRS

The following list describes the different protocol functions:

- **GPRS Tunneling Protocol (GTP).** Operating between the SGSN and the GGSN, this important protocol is used to establish the parameters of a mobile station's connection to external networks and then to transfer user data. Packets addressed for an MS that originate from external networks like the Internet reach the GGSN by using conventional IP routing methods. The GGSN encapsulates these IP packets inside GTP packets, and sends them to the SGSN for delivery to the MS. This type of communication between the GGSN and SGSN is called tunneling. The new packets include headers that contain information like an identifier for the tunnel end point, the type of data being sent and quality-of-service parameters. A similar process happens in the reverse direction for packets that originate from the MS.

  GTP itself operates over the standard Transmission Control Protocol/Internet Protocol (TCP/IP), using whatever underlying links are the most convenient for carriers, whether Frame Relay, Asynchronous Transfer Mode (ATM) or Ethernet.

- **Subnetwork Dependent Convergence Protocol (SNDCP).** Located beneath the network layer at the MS and at the SGSN, this protocol layer is the "glue" between standard networking protocols and GPRS-specific protocols. CDPD uses a similar layer that even has the same name. The primary functions of this layer are segmentation, where the IP packets are divided into segments better handled by lower layers, and compression. The SNDCP layer also multiplexes user data packets with signaling information that controls functions such as mobility management.

- **Base Station Subsystem GPRS Protocol (BSSGP).** Located beneath the LLC layer within the SGSN, the BSSGP sends routing and quality-of-service information between base station and SGSN over standard Frame Relay connections.
- **Logical Link Control (LLC).** Located beneath the SNDCP layer, this protocol provides a logical link between the MS and the SGSN. It is defined in a way that hides the details of the radio network from upper layers, making it easier in the future to enhance the operation of the radio link. This is analogous to the LLC layer within IEEE 802 standards that resides above different mediums like Ethernet, Token Ring, and IEEE 802.11 wireless LANs. The LLC also ciphers (encrypts) communications.
- **Radio Interface.** The layers beneath the LLC operating between the mobile station and the base station constitute the radio interface, sometimes referred to as the airlink. The medium-access control layer controls how user devices send and receive packets of information.

Modems and Platforms

GPRS is a flexible wireless access technology that is extremely useful for a variety of platforms, including mobile telephones, PDAs and laptop computers. A large number of companies have developed or are in the process of developing devices that support GPRS.

The range of devices will include:

- Mobile telephones with microbrowsers
- Smart mobile telephones that include PDA functionality
- Mobile telephones that can be used as external modems for external computers (e.g., laptops)
- PC card modems
- Modules for PDAs
- PDAs with integrated GPRS capability
- Rugged external devices for industrial applications
- Components for telemetry-based applications

Application Development

The GPRS network provides an optimal environment for application development. Customers can easily format Web-based content for mobile telephones with microbrowsers. In addition, a large number of IP-based applications can be used immediately over the GPRS network. For existing applications, customers should consider some optimization because of the nature of the wireless connection. In addition, a variety of providers offer middleware tools to facilitate application development.

Appendix D: Noncellular Network Details

This appendix contains additional information on networks introduced in the section "Noncellular Data Networks." Networks discussed include the Motient network, the Cingular Interactive network, two-way paging networks, Aerie Networks Ricochet, and the two telemetry networks, Aeris.net and Cellemetry. These networks are also compared in "Appendix E: Wireless Data Comparison Tables."

Motient Network

The Motient network, previously called the ARDIS network, is based on Motorola technology called DataTAC®. Originally developed by Motorola and IBM Corporation in the early 1980s for IBM customer engineers, this service is now available to subscribers throughout the U.S. Most customers originally used the network for vertical market applications like field service, but an increasing number of users are taking advantage of two-way messaging services on small handheld devices, such as the RIM Inter@ctive Pager.

The Motient network is best suited for applications that generate short messages and are relatively insensitive to transmission delay. The Motient network uses connection-oriented protocols that are well suited for host/terminal applications. With typical response times exceeding five seconds, interactive sessions generally are not practical over the Motient network.

The Motient network uses 25-KHz radio channels, with between one and ten radio channels in operation depending on the coverage area. Using what is called a single channel reuse approach, coverage from neighboring base stations overlaps, allowing modems to select whichever signal is stronger. This approach decreases overall system capacity but improves in-building penetration.

The Motient network is hierarchical, containing approximately 2,000 base stations that connect to 45 radio network controllers, which in turn connect to eight message switches. All messages must pass through one of the message switches. Customers connect their fixed-end networks to one of the message switches using private lines and IP or X.25 protocols.

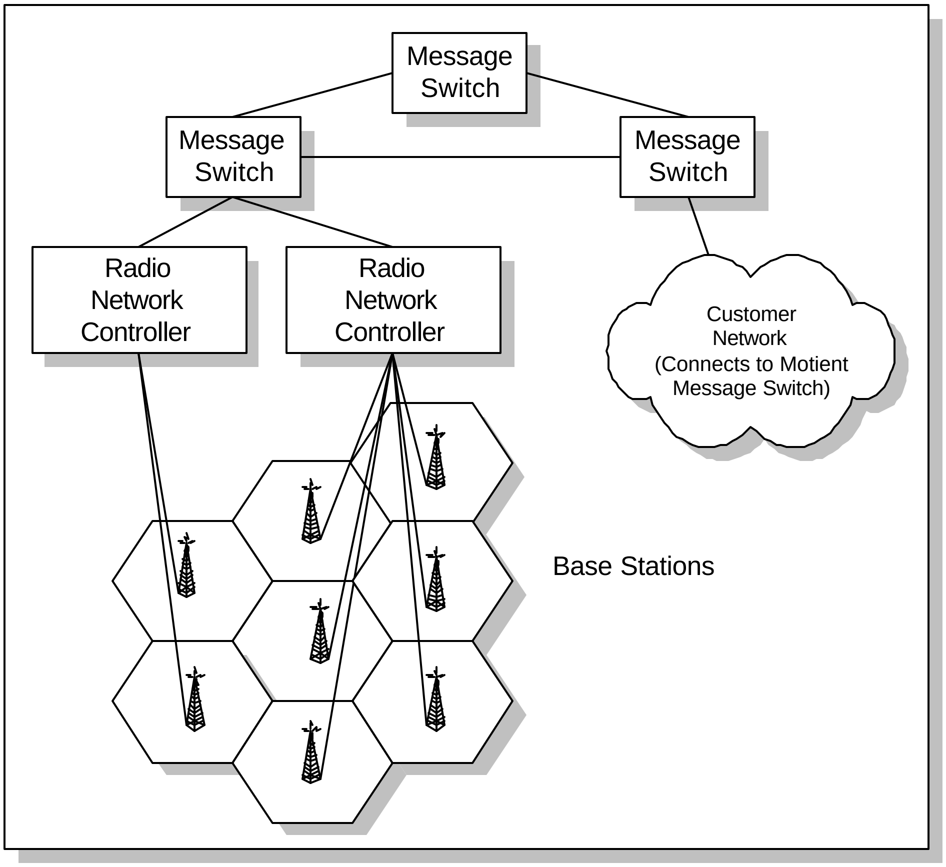


Figure 23: Motient Architecture

The Motient network, based on the proprietary DataTAC protocols, supports two different airlinks: the MDC-4800 protocol, which provides 4,800-bps service, and Radio Data Link Access Protocol (RDLAP), which provides 19,200-bps service. This is raw throughput data, including protocol overhead, and actual throughput is about half of this rate. The Motient network is in the process of being upgraded to RDLAP in certain coverage areas. DataTAC does not encrypt radio communications.

DataTAC technology was developed before the International Standards Organization (ISO) Open Systems Interconnect (OSI) reference model for networks became popular. Consequently, DataTAC protocols do not necessarily fit cleanly into the OSI model. Figure 24 and the following list show some of the key protocols used by DataTAC, none of which is based on Internet protocols:

- DataTAC Messaging (DM) is a proprietary network layer protocol.
- Native Command Language (NCL) is a proprietary protocol used to communicate with the wireless modem.
- RDLAP is a link layer, with some network layer aspects, used for the radio interface.
- Gaussian Frequency Shift Keying (GFSK) is used to modulate the radio signal.

In the Motient network, all communications go through one centralized message switch. The message switch uses a protocol called Standard Context Routing (SCR) for connecting with hosts. Below SCR, DataTAC supports protocols such as X.25 for connecting the customer's server to the Motient network.

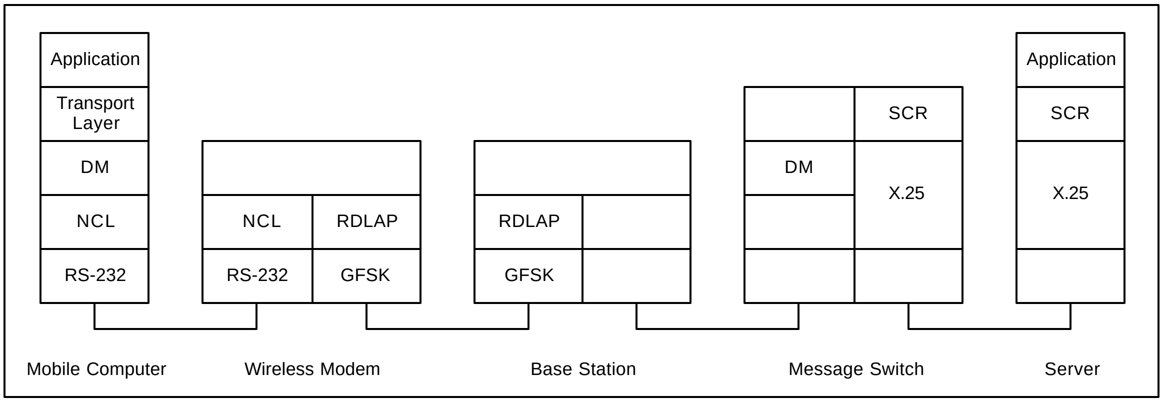


Figure 24: DataTAC Protocols

Currently, only a few companies manufacture wireless modems for the Motient network. The cost of this type of wireless modem is relatively high, since it must support both MDC-4800 and RDLAP protocols.

Developers must either support the proprietary NCL interface on the mobile end or use a middleware solution that supports the Motient network. On the fixed-end server side, the developer must support the SCR or use a middleware solution.

Relative to the Motient network, the AT&T Wireless IP and forthcoming GPRS network offer the following advantages:

- Encryption of the airlink
- Use of IP protocols, which facilitates application development and fixed-end connections
- A greater choice in user platforms, including mobile telephones, handheld computers and laptop computers
- A larger number of wireless modem options
- Higher throughput compared to the DataTAC MDC-4800 airlink and lower latencies compared to both DataTAC airlinks
- Lower usage costs, both on fixed-rate and volume-based plans

Cingular Interactive

Cingular Interactive, formerly called BellSouth Wireless Data, was originally formed as a joint venture between RAM Corporation and BellSouth to provide wireless data services in the U.S. and Canada. In October 1997, BellSouth signed an agreement to obtain total operational control of the joint venture. In March 1998, RAM Mobile Data formally changed its name to Bell South

Wireless Data, and in 2001, renamed itself Cingular Interactive after BellSouth and SBC formed their cellular joint venture called Cingular Wireless. Cingular Interactive operates a network based on technology called Mobitex, which was first deployed in Sweden in 1986. Service is currently available throughout much of the U.S., Canada and Europe. The Canadian operator Rogers AT&T Wireless operates a Mobitex network in Canada.

Customers originally used the network for vertical market applications, such as field service, but an increasing number of users are taking advantage of the two-way messaging devices, such as the RIM Inter@ctive Pager. The Palm VII also uses the Cingular Interactive network.

Mobitex protocols are controlled by the Mobitex Operators Association and are publicly available. Mobitex protocols, however, are unique to Mobitex and are not industry-standard networking protocols.

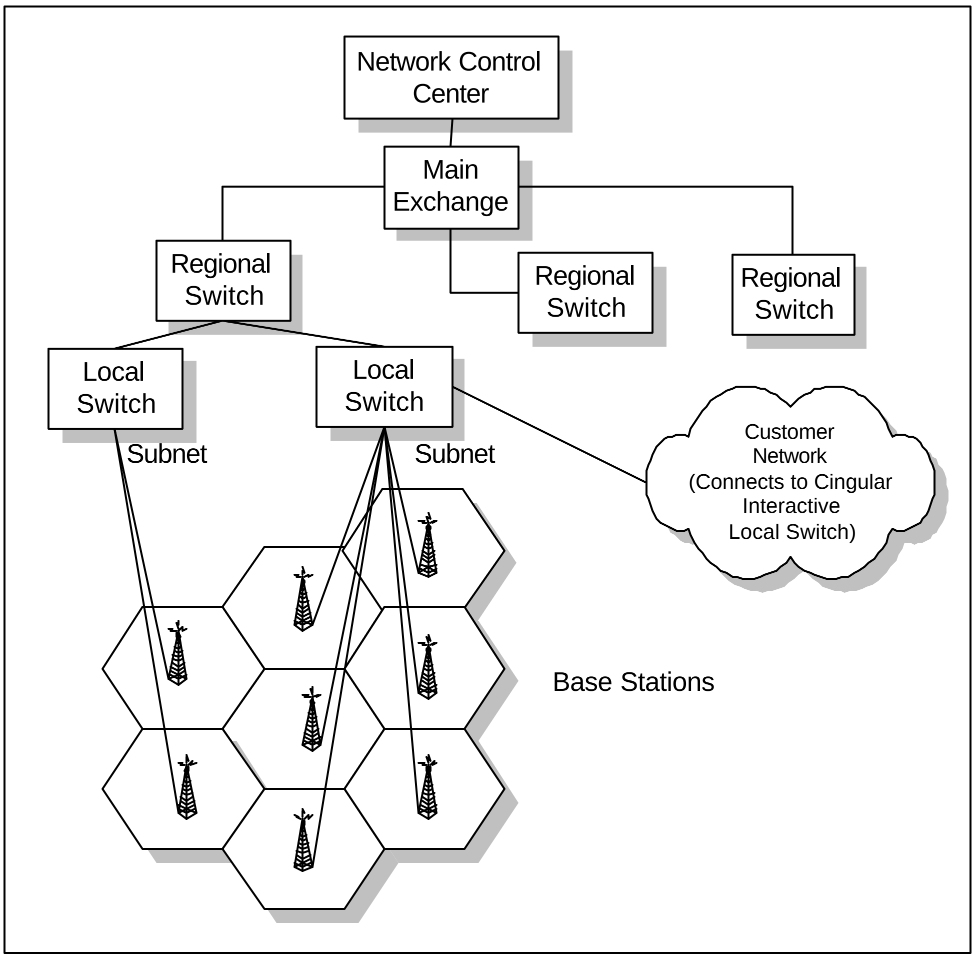


Figure 25: Cingular Interactive Architecture

The Cingular Interactive network, like the Motient network, is best suited for applications involving short messages. With typical response times exceeding four seconds, interactive sessions are not generally practical over the Cingular Interactive network.

The U.S. Cingular Interactive network consists of about 2,000 base stations operating on a cellular basis in a hierarchical network consisting of local switches, regional switches, a main exchange and a network control center. Base stations use two or three channels, with each 12.5-KHz channel supporting a raw bit stream of 8 Kbps. Actual throughput is about 4 Kbps. X.25 is the primary protocol used in the Cingular Interactive backbone network, as well as for connecting customer systems to the network.

Figure 26 shows the protocols used within a mobile-to-server connection over the Cingular Interactive network. None of these is based on Internet protocols; all are unique to the Mobitex environment. Mobitex Asynchronous Communications Protocol (MASC) is the layer that communicates with the wireless modem. Mobitex Packet (MPAK) is the Network Layer protocol. At the Transport Layer, Mobitex offers a protocol called Mobitex Transport Protocol (MTP1). Radio Open Systems Interconnect (ROSI) is the airlink and does not employ encryption.

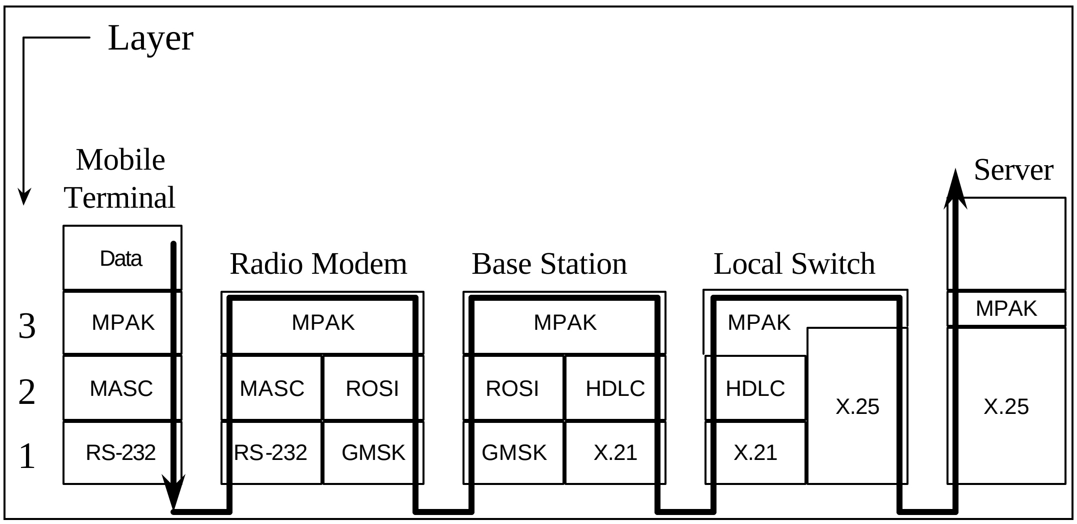


Figure 26: Mobitex Protocols

Several companies manufacture modems and devices that operate on the Cingular Interactive network. Customers can also use the RIM Inter@ctive Pager.

Application developers can support the native Mobitex protocol, MASC, or they can use a middleware solution that supports Mobitex. Working with the MASC interface requires the developer to learn the intricacies of the Mobitex protocols.

Relative to the Cingular Interactive network, the AT&T Wireless IP and GPRS networks offer the following advantages:

- Encryption of the airlink
- Use of IP protocols, which facilitates application development and fixed-end connections
- A greater choice in user platforms, including mobile telephones, handheld computers and laptop computers
- A larger number of wireless modem options

- Higher throughput and lower latencies
- Lower usage costs, both on fixed-rate and volume-based plans

Two-Way Paging Networks

A number of paging operators have upgraded their paging networks from one-way systems to two-way systems. Service providers include Metrocall, Arch Communications, , SkyTel and WebLink Wireless. To take advantage of the two-way service, customers need a two-way pager and the appropriate subscriber account. Unlike other data networks where data is transmitted on a packet-by-packet basis in real time, such as wireless IP service, paging networks transmit messages using a queuing architecture. A centralized network operations center receives messages from external networks and forwards them to a service area, which queues and transmits them as time slots become available. When the network becomes busy, messages can be delayed by periods ranging from seconds to minutes. Pagers use aggressive power management schemes to increase battery life. These schemes, which require the pager to be on only a fraction of the time, can further increase message delays.

The architecture of two-way paging involves separate transmitters and receivers. See Figure 27. Paging systems transmit at relatively high power (compared to cellular networks), using transmitters that have large coverage areas. Due to the limited power at which a two-way pager can transmit, the network requires a separate, higher density of receiver stations to receive signals from pagers. Because the receiving network's coverage area does not exactly overlap the transmit coverage area, customers may be able to receive messages, but not necessarily send them.

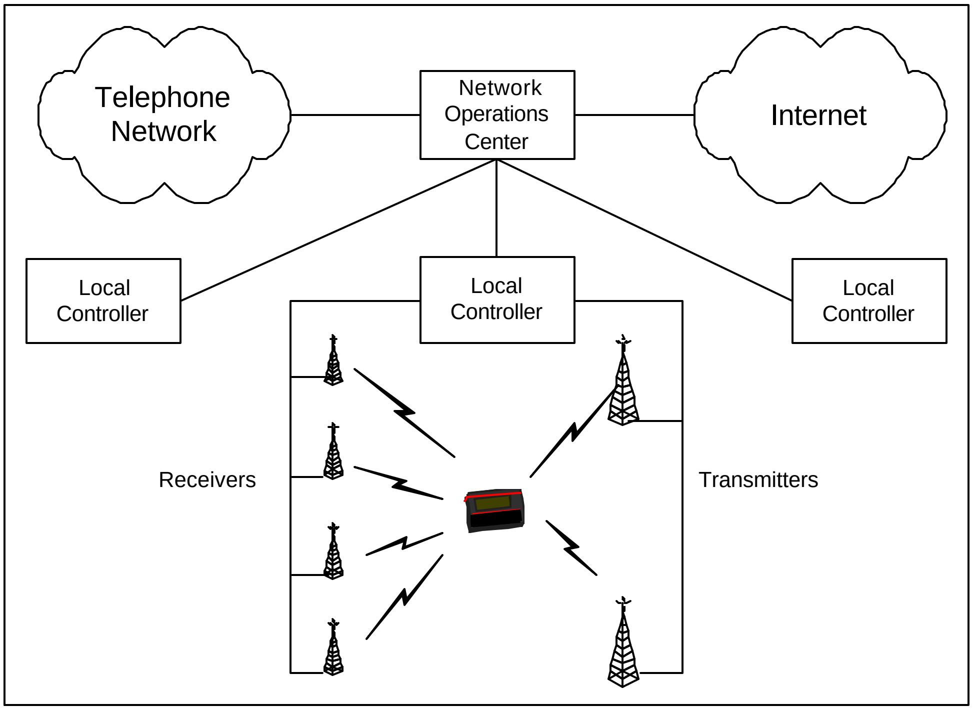


Figure 27: Two-Way Paging Network Architecture

The amount of radio spectrum available to paging operators is much more limited than that available to cellular providers: 50 KHz in each direction versus 30 MHz for a PCS provider. The result is a system with a much lower capacity, restricting the maximum size of messages that can be sent to about five hundred characters. Operators further restrict traffic volume by limiting the number of messages customers can send. A low-end pricing plan may have a limit of only 200 messages per month before the user incurs additional charges.

From a protocol perspective, most two-way paging networks today use the ReFLEX® protocol developed by Motorola. ReFLEX is a proprietary airlink protocol that operates between the paging network and the paging device. Messages are submitted to the paging network via the Internet or telephone connection using either paging protocols like the Telocator Alphanumeric Protocol (TAP) or Internet e-mail protocols. Paging operators also provide Web-based interfaces.

Between the limits on message sizes, the delays in sending and receiving messages, and how messages can be originated, there are a limited number of applications that can be used with two-way paging networks. In particular, applications where the user interacts with an application in real time are poorly suited to two-way paging. The best applications are messaging and delivery of news and other text-based information.

In fact, the two-way SMS capability of many cellular systems matches the capability of two-way paging networks. Customers that already have a mobile telephone may have all the messaging capability they need.

Relative to paging networks, the AT&T Wireless IP and GPRS networks offer the following advantages:

- Mobile telephones that already have a two-way messaging capability
- The ability to send much larger messages and to support a much wider range of applications, including interactive ones
- Encryption of the airlink
- Use of IP protocols, which facilitates application development and fixed-end connections
- A greater choice in user platforms, including mobile telephones, handheld computers and laptop computers
- A larger number of wireless modem options
- Much higher throughput and much lower latencies

Aerie Networks Ricochet

The Aerie Networks Ricochet network differs from other wireless data networks by using the unlicensed band from 902 to 928 MHz. Mobile stations communicate with small base stations (called repeater radios) that are attached to light poles in metropolitan areas. These repeater radios forward packets to a wired access point that has a connection to the backbone network. See Figure 28. Ricochet has been designed as a campus or metropolitan-area solution.

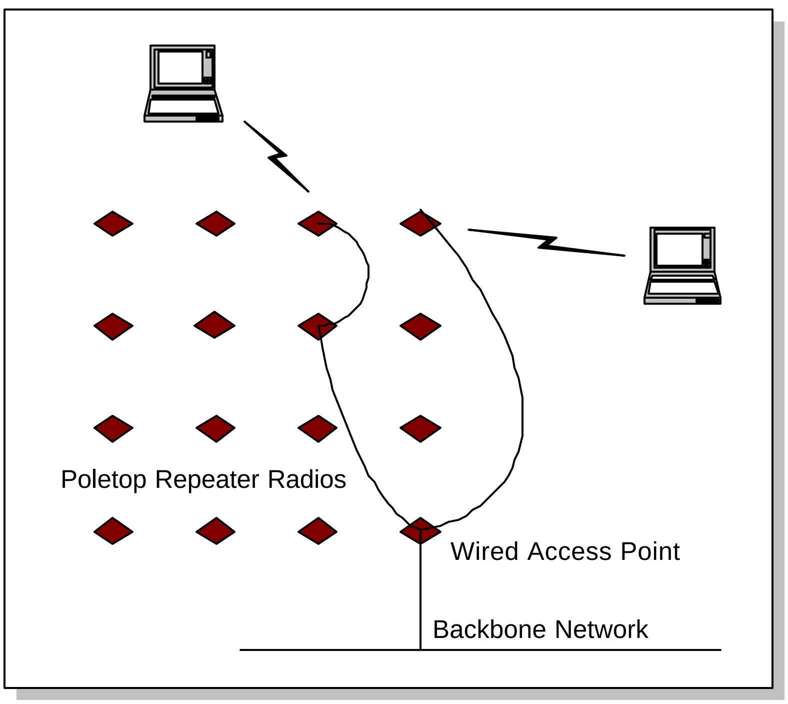


Figure 28: Ricochet Architecture

Data throughput for the Ricochet network is relatively high, as high as 128 Kbps. However, service is limited to a small number of metropolitan areas.

Since Aerie Networks uses unlicensed bands, users have secondary status. If a mobile unit's communications interfere with a primary user's communications, the mobile user must stop using the band. Additionally, secondary users must accept interference from licensed users. For this reason, users should think twice before using Ricochet for mission-critical applications.

The Ricochet network is an IP-based packet network. Customers are assigned a dynamic IP address for their session. The connection from the mobile computer to the Internet gateway uses PPP. See Figure 29.

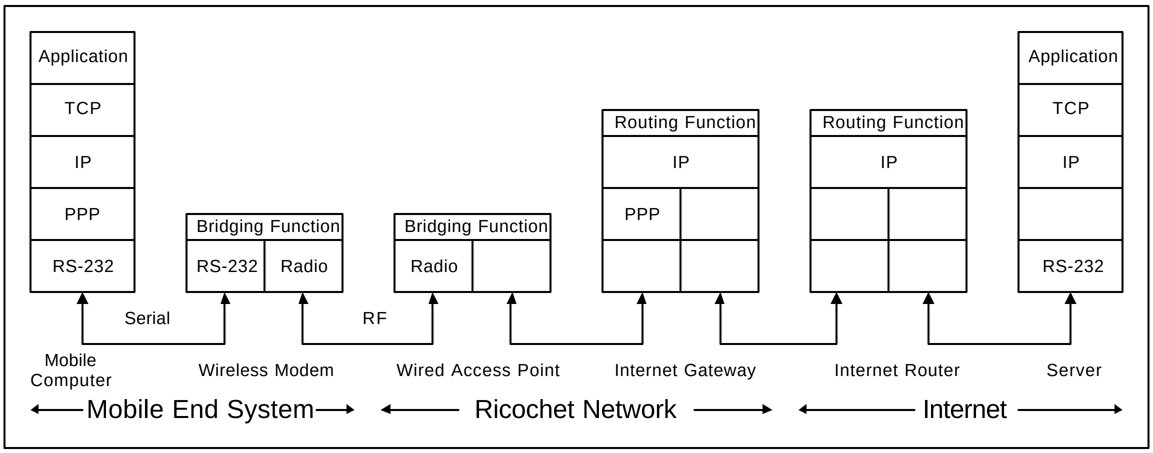


Figure 29: Ricochet Protocols

Relative to the Ricochet network, the AT&T Wireless IP and GPRS networks offer the following advantages:

- Deployment over a far greater geographic area
- Use of licensed spectrum to avoid interference
- A greater choice in user platforms, including mobile telephones, handheld computers and laptop computers
- A larger number of wireless modem options

Telemetry Systems: Aeris.net and Cellemetry

Two networks offer a specialized wireless data service for telemetry applications: one is Aeris.net™ and the other is Cellemetry® (operated by Numerex Technologies). Both networks work on a similar approach. They use wireless modems that are usually fixed, and that communicates small amounts of information over the control channels of analog cellular networks.

To the cellular network, messages from the modems appear as validation requests from mobile telephones that are in a roaming area. The messages contain what would normally be a Mobile

Identity Number (MIN), which is the telephone number of the mobile telephone, and an electronic serial number (ESN). In the case of Aeris.net and Cellemetry, the MIN is actually the ID of the telemetry modem and the ESN is a 32-bit data payload. The capacity of control channels in cellular networks is greater on the uplink (mobile to base station) than on the downlink (base station to mobile), and so the best application for these systems is where information is uploaded from remote sites to a central facility.

The messages are routed via cellular carriers' existing Signaling System 7 (SS7) control networks (using interim standard 41B protocols) to a centralized gateway operated by either Aeris.net or Numerex. See Figure 30. The cellular operator, whose network is used, must be operating in partnership with Aeris.net or Numerex. Service is obtained either directly from Aeris.net or Numerex, or via resellers of the service. Customers connect their networks to the centralized gateways using either the Internet or dedicated connections.

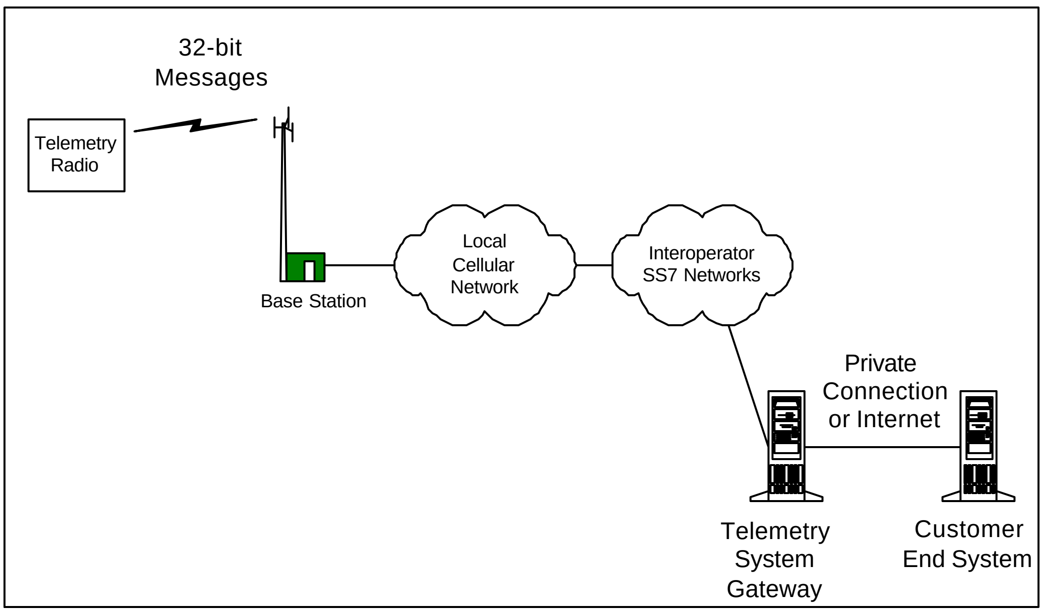


Figure 30: Telemetry System Architecture

Relative to the telemetry systems, the AT&T Wireless IP and GPRS networks offer the following advantages:

- Much greater flexibility in message size and the types of applications supported
- Much higher throughput and much lower latencies
- Encryption of the airlink
- Use of IP protocols, which facilitates application development and fixed-end connections
- A larger number of wireless modem options

Appendix E: Wireless Data Comparison Tables

The following tables summarize the capabilities, availability, coverage, performance and network characteristics of the various networks and technologies described in this white paper.

Note that the throughput of various wireless data services can be significantly enhanced by the addition of compression and middleware optimization. AW intends to provide a variety of such mechanisms for its wireless IP network service and GPRS network service.

	Data Capabilities	**Voice Service**	**System Capacity**	**% of U.S. with Coverage**	**Raw Throughput (bits/second)**	**Typical Actual Throughput (bits/second)**
AT&T Wireless IP Network (CDPD)	Packet	Yes	High	High	19,200	10,000
AT&T Wireless GPRS Network	Packet	Yes	High	High once deployed	28,000 to 56,000	10,000 to 40,000
TIA/EIA-95A CDMA	Circuit-switched airlink	Yes	High	High		13,300
Motient	Packet	No	Low	High	4,800 most areas; 19,200 some areas	2,400 most areas; 9,600 some areas
Cingular Interactive	Packet	No	Medium	High	8,000	4,000
Two-Way Paging	Message oriented	No	Low	High		Up to 9,600
iDEN	Circuit, packet	Yes	High	High		9,600 bps circuit, 19,200 packet
Ricochet	Packet	No	High	Low		28,800 128,000 with Ricochet 2
Telemetry Systems	32-bit messages	No	Low	High	Low	Low

Table 4: Comparison of Current Wireless Data Technologies

	Latency (Delay)	Wireless Modem Interface	Network Protocols	Airlink Data Encryption	Compression	Server Connection
AT&T Wireless IP Network (CDPD)	Low	PPP, SLIP, AT, NDIS	IP	Yes	Header compression, link layer compression	Private IP, Internet
AT&T Wireless GPRS Network	Low	PPP, AT, NDIS	IP	Yes	Optional V.42 bis and HTML compression	Private IP, Internet
TIA/EIA-95A CDMA	Low	AT	Async, IP	No	No	Dial-up, Internet
Motient	High	NCL (proprietary), AT	DM, SCR (proprietary)	No	No	X.25, IP
Cingular Interactive	High	MASC (proprietary), AT	MPAK	No	No	X.25, IP
Two-Way Paging	Very high	None	proprietary	No	No	PSTN, IP
iDEN	Low	AT for circuit data	IP for packet data	None for circuit data; available for packet data	None for circuit data; available for packet data	Modem, IP
Ricochet	Low	PPP, AT	IP	Yes	No	Private IP, Internet
Telemetry Systems	High		IS-41	No	No	IP or proprietary

Table 5: Comparison of Current Wireless Data Technologies

Appendix F: Acronyms

2.5G	Two-and-a-Half Generation (interim technology between Second and Third Generation [2G and 3G])
3G	Third Generation
AT	attention (commands for modems)
ATM	Asynchronous Transfer Mode
AW	AT&T Wireless
BG	Border Gateway
CDMA	Code Division Multiple Access
CDPD	Cellular Digital Packet Data
DM	DataTAC Messaging
EDGE	Enhanced Data Rates for GSM Evolution
EGPRS	Enhanced General Packet Radio Service
ESMR	Enhanced Specialized Mobile Radio
ESN	Electronic Serial Number
ETC	Enhanced Throughput Cellular
FCC	Federal Communications Commission
GFSK	Gaussian Frequency Shift Keying
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HTML	hypertext markup language
HLR	Home Location Register
HSCSD	High-Speed Circuit Switched Data
iDEN	Integrated Dispatch-Enhanced Network
IP	Internet protocol
ISO	International Standards Organization
LAN	local-area network
MDBS	Mobile Data Base Station
MD-IS	Mobile Data Intermediate System
MIN	Mobile Identity Number

MS	mobile station
NCL	Native Command Language
OSI	Open Systems Interconnect
PCS	Personal Communications Service
PDN	Public Data Network
PDP	Packet Data Protocol
PPP	Point-to-Point Protocol
PSTN	Public Switched Telephone Network
RDLAP	Radio Data Link Access Protocol
SCR	Standard Context Routing
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module
SLIP	Serial Line Internet Protocol
SMR	Specialized Mobile Radio
SMS	short message service
SS7	Signaling System 7
TAP	Telocator Alphanumeric Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Telecommunications System
VPN	virtual private network
WAN	wide-area network
WAP	Wireless Application Protocol