Network Design Manual

Peter Rysavy

Introduction

Network Computing: http://www.networkcomputing.com/netdesign/wireless1.html

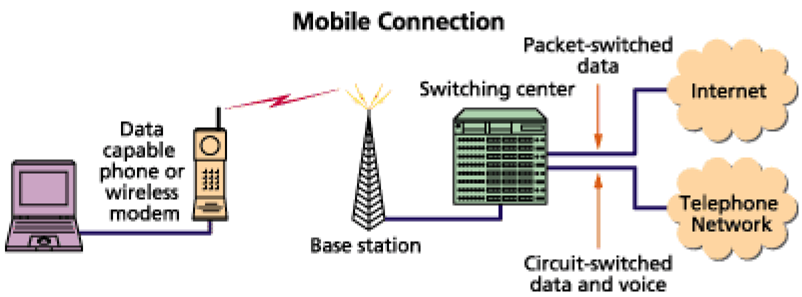
Once you begin using wireless data, you'll wonder how you ever lived without it. Wireless data gives you the freedom to work from almost anywhere and gives you access to personal information when you are on the go. Whether the wireless system is accessing e-mail from an airport or receiving dispatch instructions as a taxi driver, you'll find it extremely effective to be able to maintain a data connection with a remote network from almost anywhere.

Radio communications has been with us for a long time, with analog voice as the principal application. Today, tens of millions of people in the United States are using two-way radio for point-to-point or point-to-multipoint voice communications. Although engineers have known for some time how to modulate a radio signal to send binary data, only recently have they been able to develop and deploy wireless data services on a large commercial scale.

Wire or fiber-based data communications spans a huge range of throughputs and distances--28.8 Kbps over a modem connection; 10/100 Mbps over an Ethernet segment; and gigabit speeds over fiber. Similarly, wireless connections span a huge range. The world of wireless data includes fixed microwave links, wireless LANs, data over cellular networks, wireless WANs, satellite links, digital dispatch networks, one-way and two-way paging networks, diffuse infrared, laser-based communications, keyless car entry, the Global Positioning System and more.

The benefits of wireless include connections when no others are possible, connections at lower cost in many scenarios, faster connections, backups to landlines, networks that are much faster to install and data connections for mobile users. That last benefit is the focus of this chapter.

In this chapter, we'll concentrate on wide-area wireless data; a future chapter will discuss wireless LANs. The types of WANs we will examine include cellular-based systems, paging networks and dedicated wireless WANs, such as CDPD, Metricom's Ricochet, ARDIS and RAM Mobile Data.



First, let's walk through a planning process that highlights the key issues in working with wireless data. From there we drill into the technology, including protocols and interfaces, hardware, middleware. Next we survey the various wireless networks. We conclude with some pointers for integrating your wireless solution.

One important distinction in the uses wireless data is between vertical market applications and horizontal market applications. In vertical markets, applications addresses a very specific business need for a particular company or industry. The applications provides a clear benefit through higher productivity or other competitive advantage. Today most wireless applications are in the vertical arena. But wireless vendors strongly desire to address much larger horizontal markets where a broad spectrum of business users and consumers wil l use wireless communications. This transition will occur once wireless communications is inexpensive enough, broadly deployed and easy to use and once a large number of off-the-shelf applications are available. We are rapidly approaching this stage.

Planning

You must consider a number of issues before you use wireless data. In this section we evaluate your requirements step by step and help you identify areas to focus on. You will then be in a better position to evaluate the various wireless networks that are available for your application.

General Issues

Protocols and interfaces, hardware and wireless middleware will be discussed in subsequent sections, but let's introduce these subjects now. One of the most important considerations in choosing a wireless network is selecting the protocols and interaces to use. They determine to a great extent how your wireless application accesses the services of the wireless network and what types of applications are feasible. See Protocols and Interfaces for more detail.

With hardware, the issues of form factor, power consumption and cost come into play. See Hardware for more detail.

Wireless middleware can insulate your application from problems like intermittent connections and specialized protocols. Some applications will work well over wireless connections as is, but some will work only with the assistance of middleware. Others must be rewritten completely. See Wireless Middleware for more detail.

Suitability of Your Application

The first order of business is to look closely at the kind of information you will be communicating. Wireless data communications makes most sense when:

- Data needs to be communicated in real-time
- The amount of data communicated is relatively small (tens of kilobytes rather than hundreds of kilobytes or megabytes)
- Your users are mobile and do not have convenient access to wireline connections

In evaluating which software programs make most sense for wireless connections, consider those that can limit the amount of information that is downloaded. Look for features such as progress indicators and the ability to cancel lengthy operations.

Operating Costs

Wireless communications can be highly cost effective, but its costs generally are higher than wireline communications. We have become spoiled by our use of modems over local dial-up connections that are charged a flat rate, so that first cellular telephone bill may have been a shock. But you quickly learned how to use cellphones judiciously. Similarly, wireless data services can be expensive if used indiscriminately, but reasonable if used carefully. Surfing the Web with no particular destination in mind is not a good use of many wireless networks; downloading text based e-mail is.

Examples of usage charges are as follows:

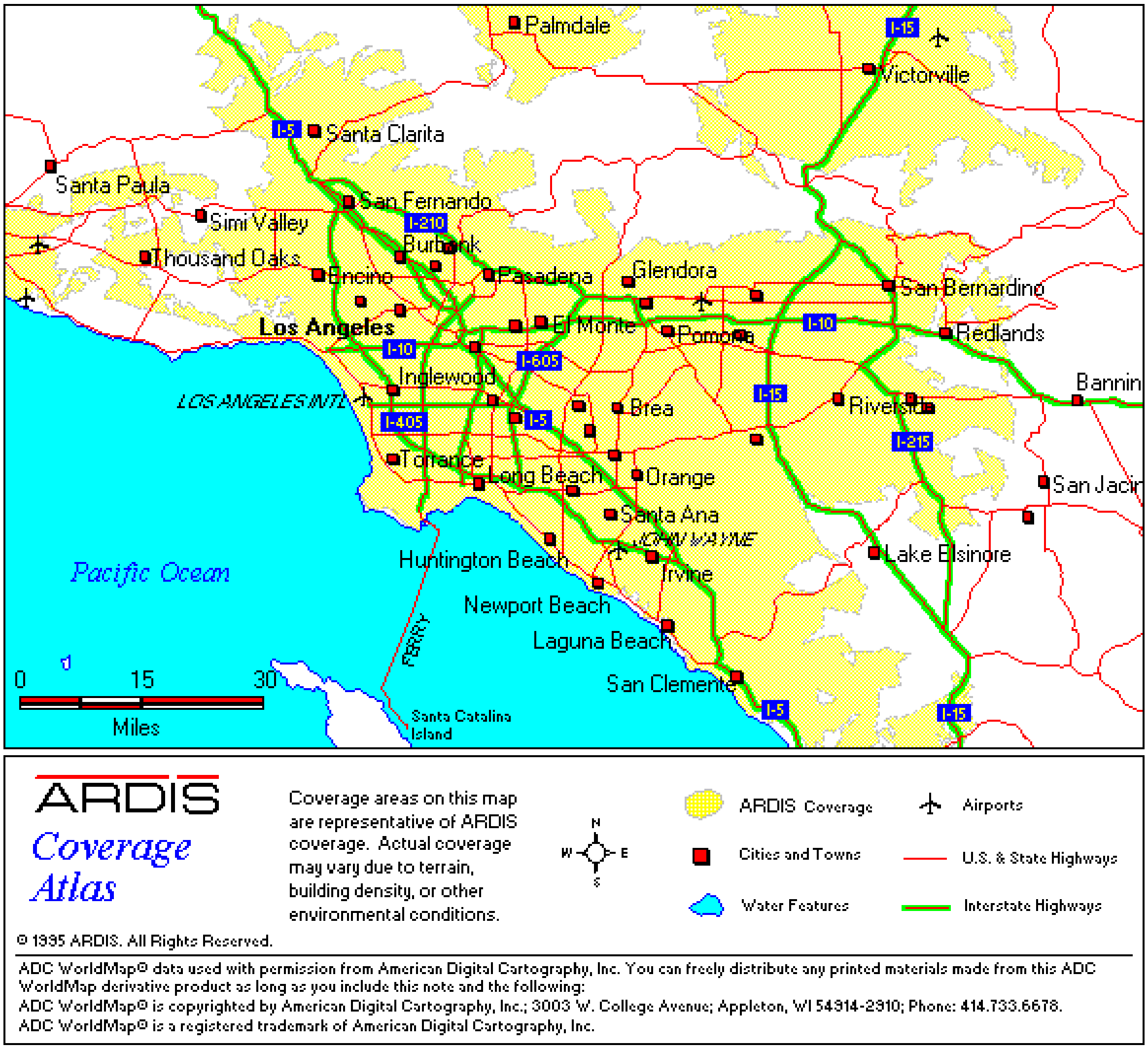
Network	Usage Costs
Data over analog cellular (such as cellular service from AirTouch, AT&T Wireless Services , Bell Atlantic)	Pay for duration of call. Same cost as for voice, about 30 cents per minute in home area, $1 per minute when roaming.
Packet data networks (ARDIS, CDPD, RAM Mobile Data)	Usually pay for amount of traffic. Rates vary between about 3 cents and 30 cents per kilobyte. Some networks charge on a flat-rate basis.
Two-way paging networks (Skytel)	About 25 cents per 80 character message.
Satellite (Iridium, Globalstar)	$1 to $3 per minute (these services are not yet available).

Analyze your application for the amount of time or the amount of data you expect to communicate. For instance, with a TCP/IP application you might run it over a Windows 95 Dial-Up Networking connection, and look at the status screen for a count of bytes sent and received. Other TCP/IP stacks, e.g. from WRQ can provide even more detailed statistics.

Coverage

Most wireless networks provide broad coverage areas, but no service extends everywhere yet. You need to evaluate where you need coverage and choose a wireless network accordingly. Packet networks, such as ARDIS, CDPD and RAM Mobile Data, offer coverage in most major metropolitan areas (though for only the dense population areas and not outlying areas). Some networks are available only in certain cities. Metricom's Ricochet network is available in less than half a dozen cities in the United States. Our profiles of wireless networks below provides coverage information, but for complete detail you will need to consult with the specific networks. Many provide coverage maps on their Web sites.

For example, you can view ARDIS coverage maps at
http://www.ardis.com/ardis_hp/mapintro.htm



Circuit Switched versus Packet Switched

With circuit-switched connections, you have a dedicated connection for your entire session, reg ardless of whether you are communicating data. Voice or modem connections over the telephone network are circuit-switched connections. In the wireless world, the most common type of circuit-switched data connection is through a cellular telephone. Such connections are best-suited for batch operations, file transfers, faxing, database replications and other transactions where the connection is infrequent, but the amount of information transferred can be large. One reason for this is that the minimum billing unit is often one minute and almost half of the first minute is consumed by the modems training to establish a connection. Usually the application or actively involved user has tight control over connection setup and teardown.

With packet-switched connections, as used by wireless WANs, the wireless modem registers with the network, but then occupies a radio channel only while sending or receiving packets of data. Data can be transmitted almost immediately because no call setup is involved. But because of current pricing plans, most wireless WANs are best-suited for short and bursty communications. Examples include short personal messages, stock information, updates from vending machine, taxi dispatch and credit card transactions. A major advantage of packet-switched communications is that client software on the mobile computer can maintain a "logical" connection with a server for extended period of time.

Packet-switched connections tend to be more robust because a communications problem may require that a packet be resent, whereas with a circuit-switched connection the entire connection may have to be reestablished if a call is dropped.

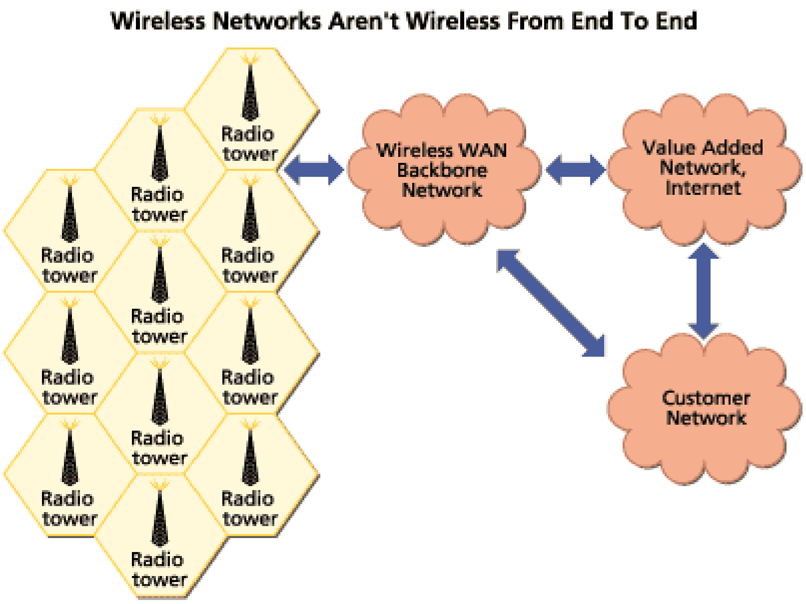
Performance

Although wireless data offers many benefits, it also poses some challenges relative to wireline connections: wireless connections can be slower, data rates can vary depending on the RF environment and connections can be lost. Wireless WANs have quoted data rates ranging from 4 Kbps to 28.8 Kbps, but actual throughput is often half this rate beca use of overhead in the communications protocols.

In addition, wireless WANs have latencies (end-to-end delays) that can range from less than a second to several seconds. For applications that involve a large amount of back-and-forth traffic, such as SQL transactions, the time to complete transactions can prove unacceptable. You must examine the nature of your application and do some actual testing to determine how well your application will function.

End-to-end communications

When we think about wireless communications, we think of data traversing a radio link. But we don't consider the entire end-to-end connection, which might involve a number of networks. Wireless networks are complex networks involving wire-line infrastructure, and they connect to other complex networks -- value-added networks, corporate intranets and the Internet.



As you can see, the wireless link is only one element of the network. In deploying your application, you'll have to consider how the mobile user will access the fixed-end services on the back end. With circuit-switched data, the fixed-end connection will be a straightforward modem link through the public switched telephone network (PSTN). But with a wireless WAN, the connection between the end service and the wireless data network could include any of the following: a wireless connection, a dedicated circuit, a connection via the Internet, X.25 or a frame relay PVC. Of these, usually a wire-line circuit is used. You will need to consider the options available for the network of interest and analyze the additional costs associated with the fixed-end connection.

Re-engineering work patterns

Human and job-related considerations are often overlooked by companies planning wireless applications. However, wireless represents a huge opportunity for companies to increase the effectiveness of their people. Because wireless communications provides a fundamental new capability, how a person does his job can change pro foundly. For example, an insurance agent that used to call a client back or make another visit to present a quote can now present that quote at the first meeting. A real estate agent can obtain listings of new properties the moment the listings become available. Police officers can instantly determine whether a particular vehicle has been stolen. Managers can stay current with their e-mail while waiting for flights.

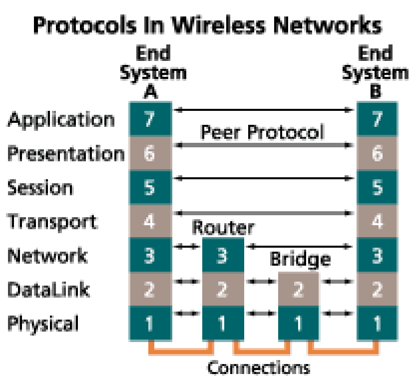
In many cases, workers not only become more productive but can do their jobs in entirely new ways. It takes time, however, for companies to fully understand and define new job structures, especially because such changes can ripple throughout an organization. You should think how wireless data might impact your company operations. Don't just consider automating existing methods, also examine how the technology can enhance the services you offer your customers.

Protocols and Interfaces

Protocols and interfaces are related topics, and are a key consideration when evaluating wireless networks.

Protocols

In many cases, the mobile computer functions as a remote node of the network you are accessing -- the Internet or a corporate intranet. If the wireless network uses the same networking protocols as the fixed-end network, connections are more streamlined, and routers can interconnect the wireless network to the fixed-end network. Otherwise, some form of gateway will be required to translate between different network protocols. For circuit-switched connections this is less of a concern because the wireless connection is essentially a Layer 1 (physical) connection, much like an existing landline modem connection. Except for wireless LANs, which are not discussed here, it is uncommon to use a bridge between a wireless network and a fixed-en d network.



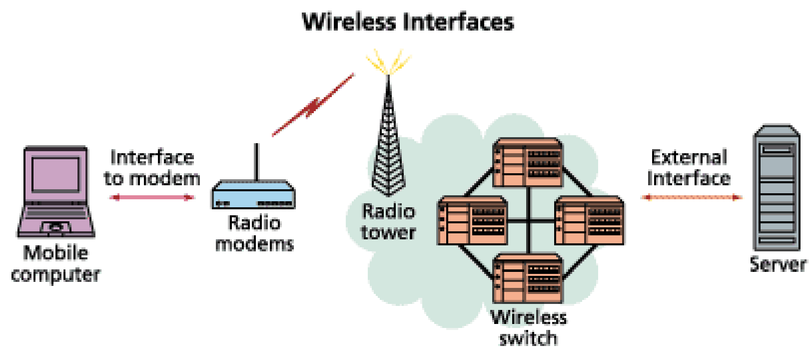
Our profiles of specific networks further below explain what specific protocols are used. But the general pattern for the wireless link is as follows.

- **Physical layer** An RF carrier signal that is digitally modulated to create a bit stream. This bit stream incorporates forward error correction, interleaving and other techniques to mitigate the effects of interference and weak signals that can produce high-bit-error rates.
- **Link layer** Usually a specialized radio protocol that employs a form of medium access optimized for the radio environment. Most link protocols involve interactions between the wireless modem and a base station, and mobile units do not communicate directly with each other.
- **Network layer** Some wireless WANs, such as RAM Mobile Data and ARDIS, use network-layer protocols designed specifically for that network, however the trend is toward using IP. This is the case with CDPD, as well as the packet services being developed for PCS networks (GSM, CDMA, TDMA).
- **Transport and higher layers** These layers usually are not part of the wireless network, but implemented as part of the application solution. Some transports have been designed specifically for wireless networks. But it is also possible to use tried and proven transports such

as TCP, though some optimization of TCP's timing parameters and algorithms tends to yield better results.

Interfaces

Where protocols determine the packaging of data for communication across a network, interfaces determine access points to the network, both at the mobile computer and at the fixed-end locations. At the mobile computer, the interfaces of interest are between the application and the protocol stack and between the mobile computer and the wireless modem. At the fixed-end, we are interested in the interfaces the wireless network presents.



Most wireless modems use a serial interface even when imp lemented as a PC Card device. Many use AT commands for configuration and control, similar to landline modems. If the network supports standard networking protocols, such as CDPD, which supports IP, then the mobile computer uses a TCP/IP stack which presents a WinSock interface to applications assuming a Windows environment. CDPD modems then use the Serial Line Interface Protocol (SLIP) or Point-to-Point (PPP) to communicate between the computer and the modem.

If the network uses unconventional networking protocols, the software interfaces are more likely to be unique or proprietary to that network. See Profile of Wireless Networks for the specific details of each network. One new approach wireless modem vendors are taking is to develop NDIS drivers with wireless extensions for their wireless modems. These wireless extensions have been defined by the Portable Computing and Communications Association (http://www.pcca.org), an organization that develops standards for wireless networking.

Wireless middleware solutions typically present a standard interface such as MAPI or a virtual file system, or use proprietary interfaces. Narrowband Sockets (NBS) is middleware designed for wireless networks and presents a WinSock interface.

Hardware

In selecting wireless hardware, you need to consider form factor, power consumption, cost and hardware compatibility.

Form Factor

First-generation wireless modems were somewhat bulky and heavy. For example, the Mobidem modem for the RAM Mobile Data network weighed more than 1 pound. But today you can purchase PC Card modems (Type 2 or Type 3) for most wireless data networks. Some of these are fully integrated; others use a short cable to an RF module. Most use their own battery.

If you are integrating a wireless modem into a product, you will find that many wireless modem vendors offer OEM modules designed specifically for vertical market applications.

Power Consumption and Battery Life

Most wireless modems today draw power from a battery, though some are powered by the mobile computer. Wireless modems typically transmit in the 100 mW to 1 W range. Because the amount of power that needs to be supplied by the battery can be almost five times higher than the actual transmission power, the battery life of a wireless modem is typically limited to a day of normal use. Test the battery life of the modems you are considering for your application, and keep in mind that transmitting data consumes significantly more power than receiving.

Cost

Wireless modems are complex electronic devices, containing interface logic and circuitry, sophisticated radios, considerable central processing power and digital signal processing. As such, they cost more than landline modems. Most wireless WAN modems cost $500 or more.

If using a cellular connection, all you need is a PC Card modem that supports cellular protocols, such as MNP10 or ETC, and a compatible cellular telephone.

Hardware Compatibility

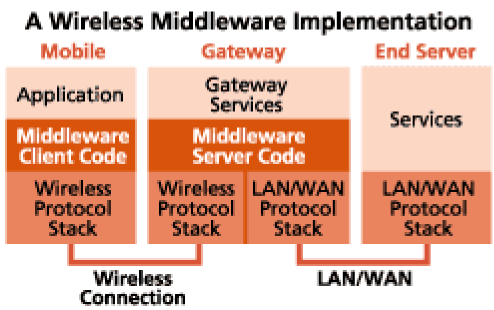
If using an external modem, your connection will probably be a serial connection, and you should not experience any compatibility issues. If you are using a PC Card modem, make sure you test your modem and mobile computer together. You could run into a compatibility problem related to radio frequency interference, heat or power fluctuations.

Wireless Middleware

Wireless middleware is software that insulates applications from the underlying wireless network, making it easier to develop new wireless applications, as well as to port existing applications to the wireless environment.

How it Works

Wireless middleware usually consists of client and server software. The client portion resides on the mobile computer and accepts messages from applications on the mobile computer. It reformats these messages and forwards them across the wireless network using application-layer protocols optimized for wireless communications. The messages reach the middleware server, which typically resides on the destination LAN. The middleware server functions as a gateway to other servers and hosts on the LAN, acting as a proxy for the mobile computer.



Middleware performs the following types o f functions, though specific details will vary depending on the actual middleware.

- Isolates the application from connectivity issues such as intermittent connections and varying throughput.
- Minimizes the amount of data sent over the wireless connection.
- Reduces the number of back-and-forth messages required to complete a transaction.
- Queues messages when a connection is not available.
- Provides a consistent API regardless of the underlying network.

Some wireless middleware products come as toolkits with which you can develop customized wireless applications. Others work in conjunction with existing applications to make these applications effective both from a cost and performance perspective.

Some Middleware Solutions

There are a number of wireless middleware providers. The following lists some of the more important market offerings.

COMPANY AND PRODUCT	MIDDLEWARE FUNCTION
IBM - Artour (www.ibm.com)	Optimizes wireless access of Web servers.
>Motorola - AirMobile (www.motorola.com)	Optimizes wireless access of Lotus Notes and cc:Mail.

NetTech Systems - Talk/Thru RF series (www.nettechrf.com)	Toolkits for developing wireless applications.
Oracle - Oracle Mobile Agents (www.oracle.com)	Toolkits for developing wireless applications. For more information, see Message Middleware in a Wireless Environment (by Peter Rysavy, Network Computing, April 15 1996)
Racotek - Keyware (www.racotek.com)	Toolkits for developing wireless applications.
Software Corporation of America - TalkThru (sca. talkthru.com)	Optimizes wireless host-terminal computing.
Sybase - Enterprise Messaging Services (EMS) (www.sybase.com)	Toolkits for developing wireless applications.
Unwired Planet - HDML and HDTP (www.uplanet.com)	Optimizes wireless access of Web servers. Web server can also host a complete mobile application.
Xcellenet - RemoteWare (www.xcellenet.com)	Toolkits for developing wireless applications.

Profile of Wireless Networks

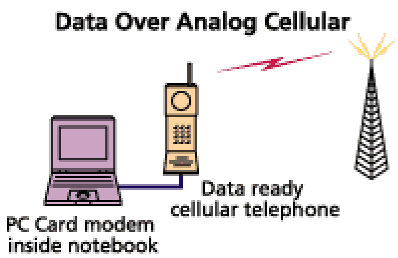
In this section we profile the major wireless data networks available in the United States. After introducing each network, we characterize it in a table.

Analog Cellular Systems
Digital Cellular Systems and PCS
Cellular Digital Packet Data
ARDIS
RAM Mobile Data
Metricom Ricochet
Paging (One way and two way)
Enhanced Specialized Mobile Radio
Satellite

Analog Cellular Systems

No wadays it is practical to send data over the analog cellular network. In the United States, this network is based on the Advanced Mobile Phone Service (AMPS) standard. Many new PC Card modems come equipped with cellular protocols and can be connected directly to a cellular telephone.

The key issue is that the fixed-end modem at the other end of the connection needs to support the same cellular protocols as the PC Card modem. Cellular carriers are addressing this issue by installing modem pools that provide a gateway function between cellular and landline modem protocols.

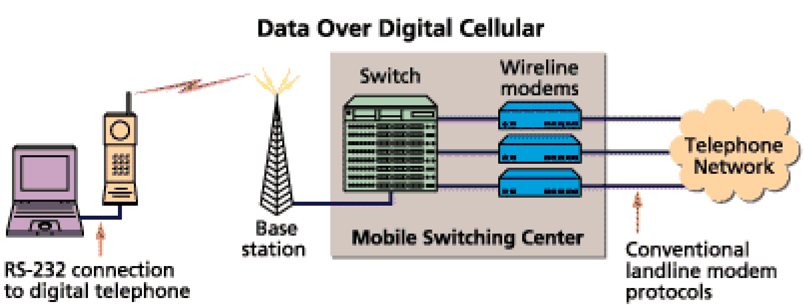


ITEM	CHARACTERISTIC
Service providers	All cellular telephone companies. The FCC has licensed cellular spectrum to two operators in each geographic area.
Coverage	The best coverage of any wireless system. Nearly every metropolitan area in the United States, as well as major highways. Modem pool coverage more limited.
Spectrum	50 MHz total shared between two carriers.
Current markets	Vertical market and horizontal markets.
Value-added services	Modem pools, sometimes also called *DATA service, which allow reliable data calls to fixed-end modems that do not support cellular protocols. Check with cellular provider for details as service details vary.
Best applications	Any application that uses modem communications where sessions are relatively short and tightly controlled by the application or monitored by the user. Batch-oriented data transfers are ideal such as uploading and downloading e-mail in bulk.
Architecture	Base stations connect to mobile switching centers which connect to the PSTN.
Protocols	Modem protocols optimized for cellular communications include ETC (Enhanced Throughput Cellular) from Paradyne, MNP10 and MNP10-EC (Enhanced Cellular) from Microcom, TXCEL (Throughput Accelerator, a waveshaping technology) from Celeritas, and EC^2 (Enhanced Cellular Control) from Motorola.

Data throughput	Typically 4,800 bps or 9,600 bps. 14,400 bps possible under ideal conditions. Future cellular protocols promise rates to 21,600 bps.
Network latency (round trip time)	Comparable to landline modem connections. Typically less than 100 milliseconds.
Modem vendors	Nearly all PC Card vendors support cellular protocols, many in their standard products. Note that each modem only supports certain makes and models of cellular telephones.
Service pricing	Usually same as cellular voice calls, about 30 cents per minute for home area calls and $1.00 per minute for roaming calls.
More information	See Cellular Data Communications Made Easy (article by Peter Rysavy in July 1, 1997, issue of Network Computing online)

Digital Cellular Systems and PCS

Digital cellular systems transmit information between the cellular telephone and base station in digital form, including encoded voice communications. PCS systems use the same technology as digital cellular, but occupy new higher frequency bands. Compared to analog cellular, digital cellular systems offer security through authentication and encryption, short message service (similar to paging), more flexible data services, a variety of value-added voice services (such as caller ID), longer battery life, higher capacity and ultimately lower cost of deployment per subscriber. Though data services have received lower priority than voice, many analysts believe that data traffic will exceed voice traffic within a decade. Data services will include both circuit-switched and packet-switched offerings.

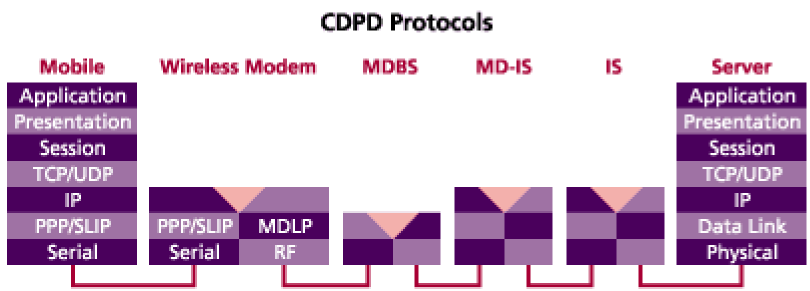


ITEM	CHARACTERISTIC
Service providers	Cellular and PCS carriers, though not all yet offer data services. Principal technologies include IS-136 Time-Division Multiple Access (TDMA), Global System for

	Mobile Communications (GSM), and IS-95 Code Division Multiple Access (CDMA).
Coverage	Eventually every metropolitan area in the United States, as well as major highways. Digital cellular and PCS coverage currently very fragmented.
Spectrum	50-MHz analog cellular spectrum will eventually be all digital. PCS spectrum consists of 120 MHz in the 1.9 GHz band.
Current markets	Vertical market and horizontal markets.
Value-added services	None yet.
Best applications	Most modem-based applications, including faxing, should be compatible with circuit-switched data service. Any IP-based application should be compatible with the packet-switched data service.
Architecture	Base stations connect to Mobile Switching Centers which connect to the PSTN. Packet service will connect with the Internet.
Protocols	The radio link uses network specific protocols that provide reliable transfer of data.
Data throughput	Most initial circuit-switched data offerings will operate at 9,600 or 14,400 bps. Various schemes are being developed to offer data at rates of 28,800 bps or even 64,000 bps. Packet data rates will range from 9,600 bps to 64,000 bps.
Network latency (round-trip time)	Comparable to landline modem connections for circuit-switched data, slightly higher delays for packet-switched connections.
Modem vendors	Modems will typically be incorporated into cellular telephones, though for GSM phones, a separate PC Card is sometimes required.
Service pricing	Circuit data usually same as cellular voice calls, about 30 cents per minute for home area calls and $1.00 per minute for roaming calls. Digital cellular and PCS pricing plans are changing constantly, so check with the carrier. Packet data pricing not yet available.
More information	See Digital Cellular Networks; On the Road to PCS (by Peter Rysavy and Craig Mathias, Network Computing, February 15 1996).

Cellular Digital Packet Data (CDPD)

CDPD is an IP-based packet data technology that is deployed as an overlay to the analog cellular network. Packets of data are transmitted either over idle voice channels in some networks or over dedicated channels in other networks. Service, offered by cellular carriers, is available in most major cities in the United States and Canada.



ITEM	CHARACTERISTIC
Service providers	The principal providers in the United States include Ameritech, AT&T Wireless Services, Bell Atlantic-NYNEX, and GTE. Canadian providers include BC TEL Mobility and TELUS Mobility.
Coverage	Most major cities in the United States and Canada.
Spectrum	CDPD uses a shared 30-KHz analog-cellular channel. Carriers can add additional channels as demand increases.
Current markets	Mostly vertical at this time, though current emphasis is on developing horizontal and consumer markets.
Value-added services	Various information services will be available for CDPD capable smart phones. GoAmerica (GoAmerica) at www.goamerica.com
Best applications	Ones using short and bursty messages.
Architecture	Existing cellular base s tations are upgraded with communications equipment referred to as the Mobile Data Base Station (MD-BS). The MD-BS bypasses the rest of the cellular network and connects to a central routing function called the Mobile Data Intermediate System (MD-IS). The MD-IS routes IP traffic to value added networks, customer networks and the Internet.

Protocols	The mobile computer and the modem exchange IP datagrams using SLIP or PPP. The modem routes data to and from the MD-IS over a Mobile Data Link Protocol. Interconnections to other networks are through conventional routed IP connections.
Data throughput	19,200 bps raw throughput. Actual throughput is 10 to 12 Kbps.
Network latency (round trip time)	Typically less than 1 second.
Modem vendors	Wireless modems available from INET, Motorola, Novatel, PCSI, Sierra Wireless and Uniden. Smart phones that combine a cellular telephone and CDPD modem available from Mitsubishi, PCSI and Samsung.
Service pricing	Approximately 10 cents per KB depending on pricing plan.
More information	www.cdpd.org for information about CDPD from the CDPD Forum. See Wireless Data Made to Order (by Peter Rysavy, Network Computing, March 15, 1996.)

ARDIS

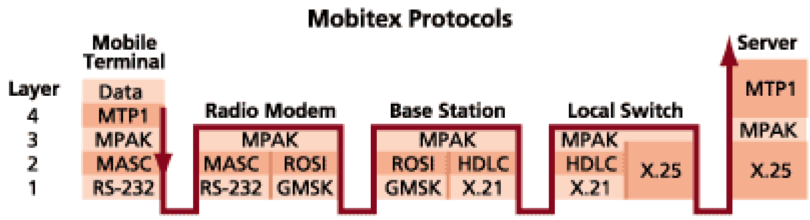
ARDIS, a wireless WAN owned and operated by Motorola, was developed by Motorola and IBM in the early 1980s for IBM customer engineers. A number of networks around the world, operated by other carriers, are based on the underlying DataTAC technology.

ITEM	CHARACTERISTIC
Service providers	ARDIS (owned by Motorola) in the United States. Other carriers in foreign countries.
Coverage	Top 400 metropolitan areas in the United States serving 80 percent of the population and 90 percent of business locations.
Spectrum	Nationwide 25-KHz channel. Up to 6 channels available in some markets.
Current markets	Mostly vertical.

Value-added services	E-mail, Internet and fax gateways: Radiomail (Radiomail) at www.radiomail.net Interactive paging using the Inter@ctive pager from Research in Motion.
Best applications	Ones using short and bursty messages. Well-suited for character-based host/terminal session-oriented applications.
Architecture	Based on Motorola DataTAC technology. A hierarchical network where base stations connect to Area Communications Controllers that connect to Message Switches. Customers' fixed-end systems connect to Message Switches. Network offers excellent in building coverage.
Protocols	MDC-4800 and MDLAP used over the air. Networking protocols are unique to DataTAC. Fixed-end connections typically over X.25 links.
Data throughput	4,800 bps raw throughput for MDC-4800 (nationwide coverage). Actual throughput about one half this rate. 19,200 bps raw throughput for RDLAP (limited coverage). Actual throughput about one half this rate.
Network latency (round trip time)	4 to 10 seconds
Modem vendors	Motorola, IBM and Research in Motion. External, PC Card and OEM versions available.
Service pricing	Approximately 30 cents per KB depending on pricing plan.
More information	www.ardis.com for information about ARDIS. www.motorola.com for information about DataTAC technology (search on DataTAC in the home page).

RAM Mobil e Data

RAM Mobile Data is a joint venture between RAM Corporation and BellSouth. This wireless WAN is based on Mobitex technology which has been deployed in 17 countries worldwide.



ITEM	CHARACTERISTIC
Service Providers	RAM Mobile Data in the United States. Other carriers in foreign countries.
Coverage	Coverage extends to 93 percent of U.S. business population.
Spectrum	10 to 30 12.5-KHz channels available per city.
Current markets	Mostly vertical. Increasing number of horizontal market applications becoming available.
Value-added services	E-mail, Internet and fax gateways: Radiomail (Radiomail) at www.radiomail.net Wynd Communications (Wynd-Mail) at www.wynd.net DTS Wireless (Zap-It) at www.dtswireless.com GoAmerica (GoAmerica) at www.goamerica.com Interactive paging using the Inter@ctive pager from Research in Motion.
Best applications	Ones using short and bursty messages.
Architecture	Based on Mobitex technology, controlled by the Mobitex Operators Association. A hierarchical network where base stations connect to local switches that connect to regional switches that connect to the main exchange. Customers' fixed-end systems connect to local switches.
Protocols	ROSI airlink protocol with GMSK modulation. Network layer called MPAK (Mobitex Packets). Fixed-end connections typically over X.25 links.

Data throughput	8,000 bps raw throughput. Actual throughput is about one half this rate.
Latency (round trip)	4 to 8 seconds
Modem vendors	Ericsson, IBM, Motorola, Research in Motion and US Robotics. External, PC Card and OEM versions available.
Service pricing	Approx. 25 to 30 cents per KB depending on pricing plan.
More information	www.ram-wireless.com for information about RAM Mobile Data

Metricom Ricochet

Metricom operates a packet data network using unlicensed bands. Service is oriented towards consumers, offering flat rate pricing for access to the Internet. Service is currently available only in a small number of geographic areas.

ITEM	CHARACTERISTIC
Service Providers	Metricom
Coverage	Metropolitan coverage in the San Francisco bay area, Seattle, and Washington DC. Coverage also available at various educational and corporate campuses.
Spectrum	Uses unlicensed Industrial Scientific and Medical (ISM) bands in the 902 to 928 MHz band. Other frequencies planned for future deployment.
Current markets	Mostly consumer and horizontal business markets.
Value added services	Standard account includes Internet access, newsgroups and an e-mail account. Additional services include: modem gateways through a service called Telephone modem access (TMA) and dial-in Internet access.
Best applications	Any Internet or modem-based application that operates reasonably at a maximum speed of 28.8 Kbps.

Architecture	Small base station equipment is attached to light poles throughout the coverage area. Base stations forward packets to other base stations eventually reaching a base station that has a fixed connection to the Metricom infrastructure.
Protocols	For Internet conn ections, PPP is used between the mobile computer and a router in the Metricom infrastructure to transport IP datagrams.
Data throughput	100 Kbps raw channel throughput with up to 28.8 Kbps actual throughput. Metricom promises higher throughput for the future.
Latency (round trip)	Typically less than 1 second.
Modem vendors	Metricom
Service pricing	Approximately $30.00 per month for unlimited Internet access.
More information	http://www.metricom.com/ for information about Metricom.

Paging (One way and two way)

Though paging has not been the focus of our discussion above, it deserves a quick overview because paging networks allow certain types of data to be delivered in a very efficient and cost-effective manner.

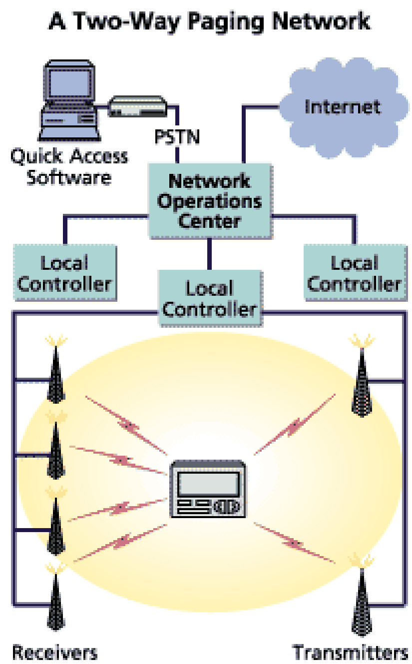
A variety of paging systems have been available over the last couple of decades, including ones that delivered single tones (effectively one bit of information), analog voice messages; numeric messages (most common today); and most recently alphanumeric messages. The most recent innovations in paging include two-way paging networks, such as SkyTel 2-Way (www.skytel.com), and digital voice messaging, such as PageNet's VoiceNow (www.pagenet.com).

Paging systems are characterized by:

- Small device size, most pagers being smaller than other kinds of wireless modems.
- Long battery life, with an AAA battery providing weeks of service.
- Limited capacity, with 500 characters usually the maximum practical message size.
- High latency, with messages potentially taking minutes or longer to be delivered.
- Queuing through carrier message systems which store and forward messages. Paging applications cannot use conventional networking protocols and real -time connections on and end-to-end basis are not possible.

- One-way systems are not completely reliable, since there is no acknowledgment from the receiver. Paging companies design their systems for ninety percent or greater reliability. Two-way networks offer higher reliability and message storage while the pager is off our out of coverage.

For more information, see Making the Call with Two-Way Paging , Peter Rysavy, Network Computing, January 15 1997.



Enhanced Specialized Mobile Radio (ESMR)

ESMR refers to new digital versions of Specialized Mobile Radio (SMR). SMR service, the precursor to ESMR, is provided by smaller operators offering dispatch types of services over relatively limited coverage areas. These service typically consists of "push to talk" analog voice communications used by the customers such as couriers, taxi fleets and construction companies.

ESMR requires more expensive infrastructure than SMR, but once deployed can deliver more flexible services to more customers at lower cost. As a consequence, large ESMR operators such as Nextel have been buying out smaller SMR companies to deploy nationwide networks. The two largest ESMR companies in the United States are Nextel using a TDMA technology from Motorola called Integrated Dispatch Enhanced Network (iDEN) and Geotek, using technology based on frequency hopping spread spectrum.

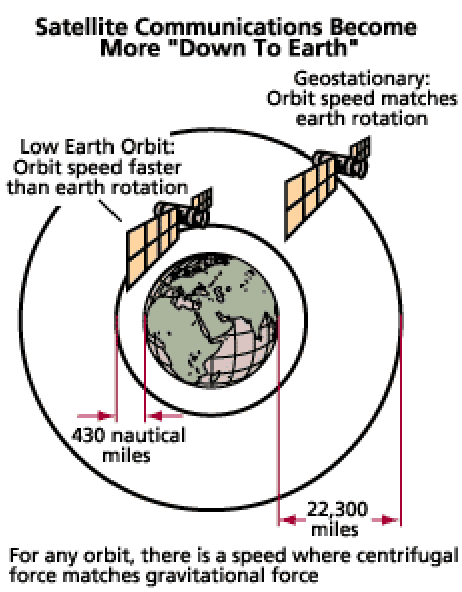
Nextel does not offer any data service, though it plans to do so in the future. Geotek (www.geotek.com) offers IP-based packet data operating at a raw throughput of 4,800 bps as part of an integrated dispatch solution.

Satellite

People have used satellites to communicate data for decades, though most communications involves fixed earth stations communicating with geostationary satellites. Only recently has it become practical to communicate data using mobile stations. Tod ay, the smallest such mobile terminal is about the size of a brief case, but that is about to change with the deployment of some half dozen different low earth orbiting (LEO) networks. These LEO networks use a larger number of satellites in orbits much closer to earth than geostationary systems. For example, Iridium will use 66 satellites at an altitude of 420 miles, compared to a typical geostationary system today that uses three satellites at an altitude of 22,300 miles. The shorter distances will substantially reduce time delays and the amount of power required for transmissions. Handheld satellite telephones will be possible for the first time.

Most mobile satellite services will emphasize voice communications, usually as an extension of terrestrial voice networks. Telephones will look like today's cellular phones, and will be able to both connect to local cellular systems if available and automatically connect to a satellite in remote areas. Globalstar expects to charge about $1.00 per minute for voice and data communications. Since data services will use voice channels, data rates for these networks will fall in the range of 4,800 bps to 9,600 bps. Carriers will offer both circuit-switched and packet-switched data services, as well as paging.

Initial satellites for some of these networks were launched in 1997, but full commercial service will not be available until late 1998 or 1999 for the first of these systems. Other satellite systems now on the drawing boards will not be deployed until the next millennium.



Future wireless broadband services

Filled with plans and grand ambitions, a large number of companies are investigating wireless broadband services. (A limited number have already been deployed.) These will offer data rates from ISDN speeds (64 Kbps) through to ATM rates (155 Mbps) and higher. Services include Mulichannel Multipoint Distribution Service (MMDS), for which spectrum is currently available, and Local Multipoint Distribution Ser vice (LDMS), for which extremely large blocks of spectrum in excess of 1 GHz will soon be auctioned, and next generation microwave systems that will apply cellular techniques to licensed microwave bands (e.g. 38 GHz) to optimize capacity. For the most part, providers are targeting these services for companies seeking high-speed Internet access or bypass of the local telephone company and are not targeting individual or mobile users.

Another contender in this space will be broadband satellite services such as Teledesic whose major differentiating feature will be providing high-speed data services (to 2 Mbps) to fixed terminals anywhere in the world. Such service should prove attractive for developing nations or industrial operations in remote locations.

In the mobile area, look to an international standards effort to develop third-generation cellular technology, called IMT-2000. Present digital cellular and PCS standards (CDMA, TDMA, GSM) are considered second-generation systems, with analog cellular being the first generation. The goal of IMT-2000 is to standardize on one technology worldwide by the year 2000, and to provide a mobile data rate of 144 Kbps, a portable data rate of 384 Kbps and an in-building fixed data rate of 2 Mbps. Given that second-generation networks are only now being deployed on a broad scale, third-generation systems will most likely not see the light of day until well into the next decade.

Integration

When you have finally decided what application, what wireless technology and what wireless devices to use, you will be ready for the integration phase. Here are some final items to consider as you integrate your solution.

Wireline Baseline

If at all possible, test your application first over LAN or modem connections. This will reduce the number of variables to evaluate if you encounter problems later with your wireless connection. If your target network is a wireless WAN or cellular connection, using wireline modems at 4,800 or 9,600 bps will give you a rough idea of what throughput to expect. This may allow you to predict how suitable an application is even before field testing over wireless connections.

Testing

Wireless connections may function in one environment yet fail in another and so it is best to test in a variety of environments and conditi ons. For instance, you may be able to simulate the loss of a connection between modem and base station by removing the modem's antenna while it is communicating. Or you could drive out of range of your coverage area. These tests will help you test the tolerance of your application to intermittent connections.

If you are using middleware that employs a server at a central site, test it under the load of multiple mobile stations simultaneously accessing it.

These are just a few examples of some tests to consider. You will undoubtedly think of others.

Pilot

Since wireless networking can pose new challenges you should consider deploying your wireless solution initially using a small number of units in a limited geographic area. Work with this pilot program long enough to understand all the technology and coverage issues. Only then deploy on a broader scale.

Partner with Network Provider or Integrator

If the learning curve for wireless computing feels daunting, choose a wireless network provider that is willing to provide some hand-holding. Or find a system integrator that has expertise in wireless data. There are a large number of integrators and value-added resellers specializing in wireless applications.

Keep in mind that not all wireless networks are fully mature, and problems that arise may not be due to your software or hardware, but due to problems in the carrier's network. Ideally you will have partners that can help you quickly identify the source of problems.

Your Efforts will be Rewarded

Despite the number of issues presented in this chapter, wireless technology is maturing, and many good hardware and software products are available. Once you deploy your system, you will be pleasantly surprised by how well this technology works, and how effective it can be.