

# Wireless-data technology: a cut above



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Many marketing pundits predicted that consumer wireless access to the Internet would be the “killer application” that would expand the market for wireless data.

However, this application, which you perform with user devices such as feature-enhanced mobile phones, PC Card radio modems, and two-way paging, is not becoming a mainstream success as fast as these pundits had hoped.

Fortunately, Internet access is driving improvements in wide-area wireless coverage, data rates, and operating simplicity. Hence, traditional vertical-market wireless applications, such as meter reading, remote dispatch, and field sales, are migrating to new, low-cost, low-power wireless-network technologies. These advances also enable useful applications for embedding wide-area wireless in products. Evolving technologies for horizontal markets increase the options for designing wireless-data technology into your application.

Mainstream horizontal-market applications for wireless data also help overcome the acceptance problems that plague the technology, such as the high cost of equipment and the perception that wireless data is nonessential to most businesses. The introduction of highly integrated chip sets for air interfaces, such as personal-communications services (PCSs) and cellular phones, has significantly reduced the cost and power needed to implement a wireless-data



ALTHOUGH MOST R&D FOR WIDE-AREA WIRELESS DATA TARGETS CONSUMER ACCESS TO THE INTERNET, THE EMBEDDED APPLICATIONS FOR WIRELESS DATA ARE ALSO BENEFITING. ADVANCES IN AIR INTERFACES, STANDARDS, AND DEVELOPMENT ENVIRONMENTS READY WIRELESS DATA FOR YOUR APPLICATION.



connection. Because of the idea that wireless data is essential only in applications such as public safety and utility-meter reading, to be competitive, these systems must cost as low as, or lower than, wired-data communications to be competitive. The R&D into wireless Internet access is paying off in cheaper equipment that makes the convenience of mobility more appealing for business.

This mobility is the obvious advantage of wide-area wireless over wired-data communications. Wireless mobility is an advantage only if coverage extends to your entire roaming domain. Because of potential-subscriber concentrations, public wireless-data network providers build their coverage in business districts. Public-service providers, such as Ardis and RAM are now approaching the 99% level for US urban areas. In addition, wireless-data-coverage options are increasing, because data carriers, such as mobile-phone and paging systems, now cover most of the United States. Applications that formerly used private dedicated wireless networks, such as public-safety applications and security-monitoring systems, can also use public networks to enhance coverage. Applications that once used wired-data transmission can now use wireless-data connections.

Global coverage at a reasonable cost is still a few years away. Satellite constellations that provide coverage

are becoming operational but have yet to offer public service. The 66-satellite iridium low-earth-orbit (LEO) system from Motorola becomes operational this year but will carry only voice, fax, and paging service. High-speed global data connections will be unavailable until next year, when the Globalstar system hopes to begin LEO service. After 2000, Teledesic (Kirkland, WA) plans to offer high-speed data communications when its LEO systems become operational. These LEO systems lower the cost and latency of two-way data return over satellite networks. The 420-mile altitude of LEO satellites allows for lightweight, low-power radio phones with shorter round-trip signal delays than higher altitude systems. However, these radio phones will remain more expensive than terrestrial-based wireless data for a few years.

#### Increasing data rates

Because Internet subscribers are impatient using anything except high-speed access, increased wireless-data rates are a primary concern for providers. E-mail access now dominates Internet wide-area wireless data because slow data rates are inadequate for browsing Web pages. However, this situation is changing. The 14- to 28-kbps data rates from networks such as Metricom's (Palo Alto, CA) Ricochet enable Web browsing on a wireless connection. Also, data rates as high as 19.6 kbps

from remarketed technologies, such as AT&T's PocketNet and Cellular Digital Packet Data (CDPD), and expanding public networks, such as Ardis' Mobile Data, attract new applications and upgrade existing ones. For example, because of increasing data rates, field-sales and -service applications can upgrade programs to run desktop applications from wireless-data connections.

Some applications need only low average bandwidth but require prioritized and low-latency bursts of information. For example, automatic meter reading and vehicle tracking don't need high data rates but require timely data updates. Other applications, such as vending and arcade-machine monitoring, fall into this category and can use public paging networks, such as Motorola's Flex one-way paging and ReFlex two-way paging. Throw in some Global Positioning System (GPS) capabilities, and navigation aids become another opportunity for products because they use little bandwidth.

Certain wireless applications demand real-time data networks. Bandwidth-on-demand applications that require guaranteed data rates and bounded latency, such as telemetry and remote control, need special consideration when you use a wireless link. If you control pump stations and wells using wireless data, the communications link must

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meet response-cycle and latency limits.

Other legacy problems associated with wireless data are a lack of through-

put and reliability. Before recent advances, real throughput—the message data received after subtracting the

overhead for coding and error checking—was typically less than 10 kbps. Reliability is more critical for wireless

**TABLE 1—NETWORK TECHNOLOGIES FOR WIDE-AREA WIRELESS-DATA TRANSMISSIONS**

Network technology	Description	Coverage	Data rate (kbps)	Latency	Frequency
Microwave communications	Analog and digital point-to-point communications carrying voice, video, and data; replaces leased lines in dedicated networks; usually privately owned and operated stationary-end nodes	Five to 50 miles, depending on topography	1000 to 45,000	Low	18, 23, and 38 GHz
Satellite communications	Geosynchronous, middle-earth-orbit and low-earth-orbit (LEO) networks proposed and implemented; two-way return presents problems with cost; Iridium and Globalstar are examples of LEO networks with moderately priced end-user devices	Global	64 to 45,000	Medium	Ku-band or C-band
Spread-spectrum microwave communications	FHSS and DSSS; FHSS is cheaper and simpler but has problems with hand-off between cells; DSSS gives wider coverage and better signal quality for the same radiated power as FHSS and accommodates more channels per spectrum	30 miles maximum between radios	1000 to 2000	Network dependent	902 to 928 MHz; 2.4 and 5.7 GHz
Paging	One- or two-way communication for tone, numeric, or short alphanumeric messages; most efficient use of spectrum for broadcasts; public carriers provide services; transmissions via satellite provide wide coverage areas	100% of the United States and most other countries	1.2	Medium to high (adjustable)	Varies
Circuit-switched cellular data communications	Transmit data over cellular and personal-communications-service networks; you establish and dedicate a circuit the way you would a wired modem connection; billing is for circuit time, independent of data amount; good for large file transfers	95% of US metro areas	14.4	Low	900 and 1900 MHz
Cellular Digital Packet Data (CDPD)	Packet-data service based on Internet Protocol; overlaid on analog cellular system by using idle voice channels for data packets; voice has priority; billing is for only the data you send and not the time it takes to send it	99.9% of US metro areas	19.2	Depends on voice-traffic load	900 MHz
Mobitex two-way packet radio	Packet-data-only network; connect protocols are UDP/IP, TCP/IP, SNA, X.25; supports transparent and seamless roaming, broadcast, store-and-forward messaging, and host or peer routing; managed by Mobitex Operators Association (Gothenburg, Sweden); developed by Ericsson (Gothenburg, Sweden)	93% of US urban business areas	8	Low	800 MHz
DataTAC two-way packet radio	Packet-data-only network; connect protocols are TCP/IP or X.25; supports transparent and seamless roaming and host and peer routing; managed by Worldwide Data Networks Operators Group (contact Ardis) and developed by Motorola	93% of US urban business areas	4.8 to 19.2	Low	800 MHz
Integrated Digital Enhanced Network (iDEN)	Combines voice, dispatch, short messaging, and future packet data; iDEN increases cellular capacity and performance with a vector-sum-excited-linear-predictor (VSELP) vocoder, quadrature-amplitude-modulation signal coding, and a TDMA system	90% of US metro areas	9.6	Low	800 MHz
Digital PCS (CDMA, GSM, TDMA)	Second-generation digital standards for voice, messaging, and data; two-way short-messaging service replaces paging for transactions such as banking; packet data will be available first for GSM, then CDMA	100% of North America	28.8	Low, depending on load	1900 MHz
Generation 3 digital cellular	Next-generation mobile-phone technology; competing proposals are from UMTS with either time-domain CDMA or wideband CDMA, W-CDMA-One from Qualcomm, and NTT's version of W-CDMA; deployment should begin around 2000	NA	Proposals for data rates from 64 kbps to 2 Mbps	Low	2 GHz

**Notes:**

FHSS=frequency-hopping spread spectrum; DSSS=direct-sequence spread spectrum. UDP/IP=User Datagram Protocol/Internet Protocol.

data than it is for wireless-voice data. High error rates in wireless-voice data can drop syllables from or add static

Security	User-device cost
No	\$12,000 to \$18,000
No	Terrestrial uplink \$5000
FHSS only	\$1000 to \$4000
No	\$30 to \$200
No	\$100 to \$400
Data Encryption Standard	\$100 to \$400
Yes	\$300 to \$700
Yes	\$300 to \$700
Yes	\$170 to \$350
Yes	\$300 to \$900
Yes	NA

noise to conversations, whereas high error rates in wireless data can be catastrophic. In addition, coverage is still spotty because of radio-signal interference and fading.

With wireless data, an inverse relationship exists between distance and throughput; the greater the distance between communicating stations, the lower the throughput and the higher the error rate. Cellular and microcellular technologies address this problem. Both reduce the distances between transmitting and receiving radios, thereby reducing the transmitted power necessary to maintain throughput and reliability.

More factors than just the raw data rate affect data throughput. For example, when you compare the raw data rates of the CDPD and Mobitex standards (**Table 1**), you see that CDPD's rate is more than twice that of Mobitex's. However, the Mobitex system is only for data, but the CDPD system waits for idle voice channels before it transmits data. Therefore, the CDPD throughput decreases as the concurrent-voice-traffic load increases. CDPD is addressing this problem by dedicating special data channels in some areas. This is not to say that the throughput on the packet-data networks equals the raw data rate. For instance, in the **table**, the DataTAC standard's throughput is typically only 13 kbps compared with its 19.2-kbps peak raw rate.

Four components comprise the design of any wireless-data system: the applications, the network, the end-user devices, and the connection between the network and the applications. You need to understand the options and trade-offs of each component to successfully assemble your design. The network is a combination of the air interface and the wired or wireless connection to a host that provides data or connection to the public switched telephone network. End-user devices, such as mobile phones and personal digital assistants (PDAs), communicate over the air interface with the host. Applications perform the tasks for the user, and the wireless-network service provider completes the connection between the user and the application.

Application-development tools are essential for meeting time-to-market demands for new products in wireless data. Mature wireless-network providers, such as RAM and Ardis, provide development support for applications in their proprietary networks. However, this proprietary development can be a problem for developers who want their applications to be independent of the physical network. Windows CE and Java solve this problem by providing open development environments for wireless-data applications.

Embedded development for Windows CE 2.0 wireless applications will present some new possibilities. Win-

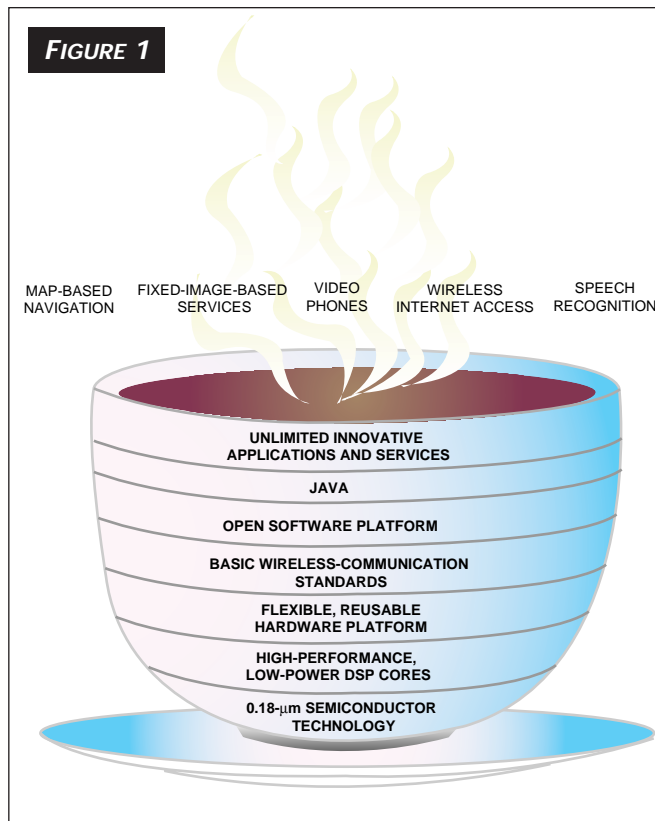
## @a glance

- Wide-area wireless data lacks a killer application but will grow through services such as e-mail, Internet access, and short messaging, which are inexpensive and easy to use and which place low demands on network resources.
- Service providers using different network technologies deliver wide-area wireless-data coverage to 99.9% of US business areas.
- The four basic components of wide-area wireless-data systems are the application, the network, the end-user device, and the connection between the application and the end-user.
- Application development through Java and Windows CE is creating a new class of wide-area wireless-data applications.
- Reduced power, size, and cost of Advanced Mobile Phone Service cellular chip sets make them attractive for embedding wireless-data communications.
- Wireless-service providers offer application-development help to fit various project requirements.

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dows CE provides the ability to customize the operating system for a product by selecting from a set of modules. The customization allows a scalable operating system to fit many needs. However, some limitations exist. The supported processors are Hitachi's (Brisbane, CA) SH3, Philips' MIPS 3900, NEC's 4100, any 486, Intel's (Santa Clara, CA) Pentium, and the PowerPC 821 from Motorola and IBM, (Hopewell Junction, NY). The memory that the operating system needs depends on which modules the de-signer selects. For instance, a wireless application that uses just the kernel and the communication stacks and uses no display requires around 500 kbytes of ROM and 350 kbytes of RAM. One drawback of Windows CE is that it does not yet support non-Microsoft e-mail and messaging applications.

Using Java in wireless-data applications became more prevalent after Texas Instruments announced that it will deliver EmbeddedJava and PersonalJava capabilities with its digital wireless-baseband platform and TMS320 family of DSPs. Nortel (Toronto) also announced that it will include Java capabilities in its wireless phones. The advantage of Java is that the software and services download over the network. The individual applications need not reside in the equipment. TI will incorporate Java into its digital wireless-baseband platform to facilitate delivery of data-intensive applications, such as map-based navigation and fixed-image-based services (**Figure 1**). PersonalJava is a Java application environment (JAE) that targets resource-limited environments and offers features that are useful to consumer applications. EmbeddedJava is a JAE designed to run on RTOSs and optimized for small memory footprints and diverse visual displays.



Java enables a new class of wireless-data applications. Texas Instruments' vision of the wireless-data-applications market incorporates Java with the company's silicon process and DSP technologies.

Many wireless-PCS-equipment providers want a standard interface for applications. Such an interface could expand the market, because it would ease users' concerns about their applications being tied to a wireless technology. Establishing this standard interface is the intention of the Wireless Application Protocol (WAP) forum that Nokia (Irving, TX), Ericsson (Totowa, NJ), Motorola, and Unwired Planet support. WAP covers the delivery of applications and data to PDAs and digital mobile phones. The application protocol would operate with any compliant device, independently of the air-interface protocol, such as TDMA, CDMA, or Global System for Mobile (GSM) communications. Using the best data-handling protocols from the vendors is necessary to make an interoperable protocol. WAP employs the Narrowband Sockets standard—which defines a network-independent

transport service for wireless messaging—to support the memory, display, and keypad abilities of data-ready mobile equipment.

#### The networks

You can choose from many wireless-network technologies (**Table 1**). All of the technologies optimize some characteristics at the expense of others. For instance, in a private network constructed from microwave communications, the data rate is high over potentially long distances, but the trade-off is that these networks present expensive end-user devices and a lack of mobility. On the other hand, paging networks provide complete wide-area coverage for a cheaper end-user device, but low data rates and subscription hassles from a public carrier are the trade-offs. It is unlikely that one wireless-network technology can meet the needs of every application.

When you look at wireless-network options, remember some general principles about radio communications. First, the higher the frequency, the greater the cost in building the RF components—even though improved semiconductor process technology enables CMOS rather than GaAs components. Also, at higher frequencies, signal propagation and penetration suffer, which can increase system cost as well. The crowded spectrum, however, requires higher frequencies. Line of sight and weather sensitivity also increasingly affect radio communications at higher frequencies. Note that more mature network technologies tend to operate at the lower frequencies.

The most mature networks for embedded wireless applications are the two-way packet-data networks: DataTAC and Mobitex. Public-service providers, such as Ardis and RAM, typically own and operate networks that use these technologies. Private net-

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works for fleet operators and safety services also use these networks. These networks are the best at carrying small datagrams, because the capacity limitations and latency uncertainties make the networks less than ideal for large file transfers or online sessions.

The two-way packet-data networks carry only data and therefore make no trade-offs for voice. They allow many devices to share bandwidth by using interlaced packets. Roaming is seamless and transparent to the user throughout the network. Network users can configure their applications for message acknowledgment and delivery options, such as store and forward. These networks usually have a low latency, but it can be unpredictable, depending on the network load. Because networks also allow peer-to-peer routing by relaying packets from radio to radio, a lot of routed traffic uses bandwidth between base stations. This traffic can cause significant overhead, as well as congestion that decreases the throughput rates in the network.

CDPD is another two-way wireless packet-data technology. CDPD uses

cellular networks to transmit data packets in the TCP/IP format. The cellular-voice-network operators add CDPD to their services to use idle channels. The frequencies for voice and data are the same, but the radio technology, protocol, and switching equipment differ, so adding CDPD requires a significant investment. A CDPD user modem is necessary, and the service provider must have the packet-data infrastructure. The investment in the packet-data infrastructure is why CDPD is not as universally available as cellular-voice service.

CDPD uses idle voice channels to make efficient use of network capacity. However, voice signaling steals channels from CDPD when necessary. At peak voice-usage times, the data-transmission latency can be unpredictable, and the throughput can be reduced. CDPD can hop to another idle channel if voice traffic pushes it out of one channel or if the CDPD user modem is moving between cells. Encrypted data and authenticity checks provide security. A built-in sleep mode conserves power in end-user devices.

Carriers are just beginning to deploy the digital PCS standards—CDMA, GSM, and TDMA—in the United States. However, because of intense competition among the carriers, airtime sells for as low as 10 cents a minute. The short-message service (SMS) that some carriers offer can be a practical way to achieve a two-way paging service. The GSM standards authority is just rolling out data-packet protocols for GSM, and roll-out for CDMA is still about a year away.

New wireless-data-network technologies include Motorola's iDEN (integrated Digital Enhanced Network) and worldwide Generation 3 digital cellular. The iDEN technology is the improved and upgraded Motorola Integrated Radio System. Mobile-phone-service carriers use iDEN to provide full digital service in the 800-MHz enhanced specialized-mobile-radio (SMR) frequency that used to carry SMR dispatch and fleet management. Voice, dispatch, and SMS are now available on iDEN networks. Packet-data services will soon be available to provide roaming Internet access (**Reference 1**).

Multiple organizations are standard-

**TABLE 2—REPRESENTATIVE CHIP SETS FOR PAGING, CELLULAR, AND PCS END-USER DEVICES**

Vendor	Chip set	Function	Price
GEC Plessey Circle No. 313	Planet	Five chips provide all functionality between the antenna and baseband for 1900- and 900-MHz bands, as well as for Advanced Mobile Phone Service and CDMA modes.	\$67.16 (10,000)
	GEM 300	Four chips, including a digital-cellular, dual-baseband processor, a baseband and audio interface, an RF front-end processor, and an intermediate-frequency processor. Complies with GSM900, DCS1800, and PCS1900 by changing the RF front-end processor.	\$35 (100,000)
	ACE	Five chips provide cellular Advanced Mobile Phone Service and Total Access Communication System handsets. Includes upconverter, dual synthesizer, audio processor, embedded compander, embedded $\mu$ P, modem, RAM, I/O interface, and keypad interfaces.	\$20 (100,000)
Lucent Circle No. 315	Sceptre	Three chips provide all functionality between the power amplifier and the speaker. Layer 1 software includes short-messaging service.	\$30 (10,000)
Texas Instruments Circle No. 321	Flex chip set	A Flex paging chip set comprises two chips, an ADC chip, and a decoder. The ADC can be a 3.3V TLV5590 or a 1.8V TLV5592. You can choose from the numeric decoder, the alphanumeric-with-roaming decoder, or the strictly alphanumeric decoder.	\$5.85 to \$7 (10,000)
	Digital Baseband Platform	Single chip integrates all digital-baseband functions for digital-wireless handsets. Modules are available for multiple worldwide standards. The Digital Baseband Platform integrates the DSP C54x with the ARM7TDMI core on an ASIC backplane.	Varies with customization
VLSI Circle No. 322	OneC	Customizable single-chip baseband processor for all Global System for Mobile standards. Integrated on-chip packet-data service for high-speed GPRS and multislot data; eliminates the need for external processing and for a PC Card.	\$12 (1 million)

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izing Generation 3 digital cellular. The Telecommunications Industry Association (TIA, Washington), the European Telecommunications Standards Institute (ETSI, Sophia Antipolis, France), and Nippon Telephone and Telegraph (NTT, Tokyo) are making proposals to the International Telecommunication Union (ITU, Geneva). ETSI promotes the Universal Mobile Telecommunications Service (UMTS). The UMTS aims to be a version of wideband CDMA that is backward-compatible with GSM. NTT is proposing a wideband CDMA that is similar to the UMTS proposal and that emphasizes data communication for such applications as multimedia and video. The CDMA Development Group, led by Qualcomm, is promoting the next generation of IS-95 as "Wideband cdmaOne" in the TIA. All three groups are approaching the ITU's International Mobile Telecommunications 2000 initiative that is until June accepting proposals for developing a worldwide standard. The proposed data rates are 144 kbps for mobile communications, 384 kbps for pedestrian communications, and 2 Mbps for stationary communications.

## End-user devices

Many varieties of end-user devices exist. Some examples are mobile smart phones, PDAs, mobile or desktop computers with radio modems, stationary or mobile heavy equipment with wireless links to a host, and electronic hiking-trail guides with GPS and navigation capability. You can design end-user devices with chips, modules, or complete radio units, or you can adapt existing products, such as those from Ardis and RAM, to fit your application.

Cellular and PCS phones are the most price-competitive products in consumer electronics. As a result, the chip sets for these devices compete over price, low power, and features. To aid your design, these chip sets come with reference designs, application notes, and software packages that help meet standards compliance (Table 2). The Advanced Mobile Phone Service cellular handset chip sets have reached maturity. This maturity makes these chip sets attractive for adding to equipment such as vending machines, so

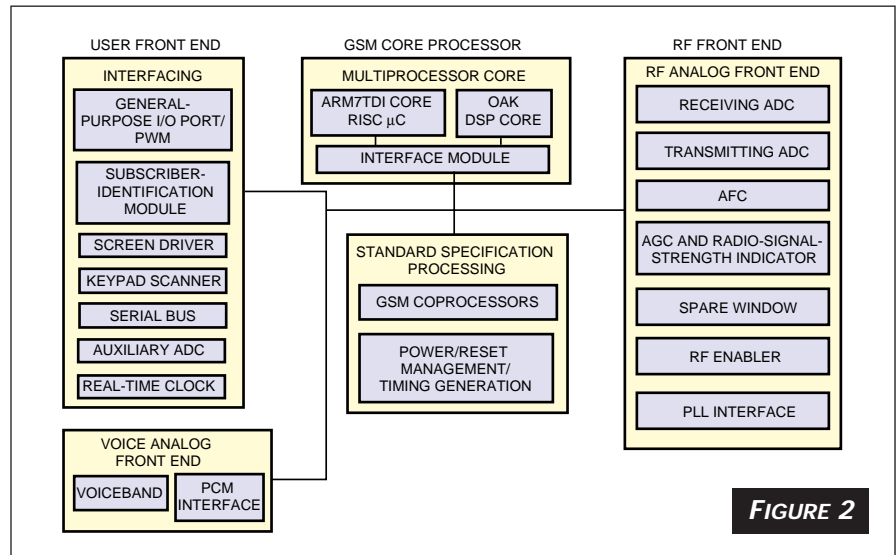


FIGURE 2

VLSI's OneC chip is a customizable single-chip baseband processor that includes General Packet Radio Services (GPRS) and short-message-service functions.

that you have two-way communications through a wireless packet-data service, such as CDPD. You can also apply cellular chip sets to security systems. Two-way wireless communication allows the monitoring station to poll the remote site to check if the system is still connected and actively maintaining security.

Most new design activity in chip sets is in the highly competitive dual-band CDMA and GSM standards areas. Both of these standards can carry data. This connection, which is similar to wired access, can be a simple circuit-switched data link that uses a dial-up radio modem, but this PCS airtime is expensive unless you use it only for small, infrequent messages. Another option for data in PCS is SMS, which is similar to paging and is available in the GSM standard and chip sets. Future developments will be CDPD that is modified for use with the PCS air interfaces as well as packet data designed for transmission in one of these networks.

The PCS chip sets make it possible to add voice, data, and even multimedia wireless communications to any end-user device. The primary applications for these chips are mobile phones, mobile computers, and PDAs. New applications, such as GPSs, are also good applications for these chip sets. Other applications for PCS chip sets

include SMRs. Private networks for public safety or dispatch for taxi and bus service previously used SMR for communications. But, because the new PCS standards—GSM and CDMA—have intrinsic data encryption, using a public network for sending private data presents no security risk.

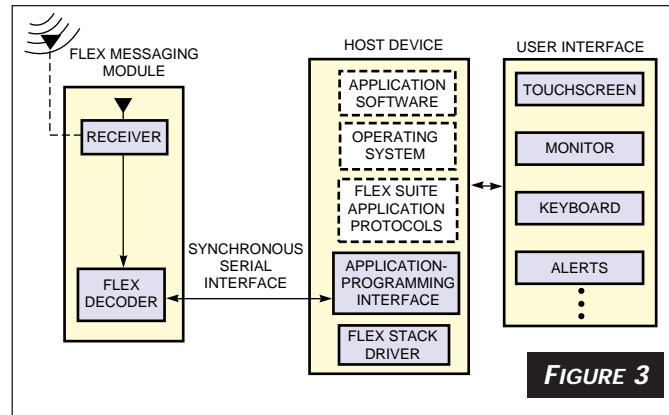
General Packet Radio Services (GPRS) is the packet protocol for use in GSM. GPRS is a recently passed sub-standard of GSM that organizes data packets for delivery over the network. The protocol allocates a channel only when a packet is ready for transmitting. This protocol makes the most efficient use of channel bandwidth by holding no channels idle. Even though the raw transmission rate for GSM is approximately 270 kbps, eight time slots evenly divide this raw transmission rate. Excluding the control and error-checking overhead, the basic bidirectional data-throughput rate is 9.6 kbps on a time-slot channel. However, GPRS employs a multislot protocol in which data packets simultaneously use multiple time slots to increase bandwidth. The theoretical maximum throughput is 76.8 kbps and results from using eight slots.

GPRS is available in the OneC chip from VLSI Technology (Figure 2). The OneC combines a modular architecture with a design-flow methodology that

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allows customization for end-user-device requirements. For example, the radio interface can have proprietary modifications, or you can modify the system firm-ware for extended functionality. The extended data functionality comes from integrated GPRS on-chip. The OneC GPRS can simultaneously use as many as three channels to achieve a maximum throughput of 28.8 kbps. The GPRS eliminates the need for external data processing as well as the need

for a PC Card for data communications on a PDA. In addition, the OneC conserves battery life by typically providing 500 hours of standby time and 7 hours of talk time. The modular architecture uses the VLSI-enhanced Vector



The Flex suite protocol stack resides on the host processor for task completion.

ARM (Los Gatos, CA) Thumb RISC processor core and the Vector Oak (Sunnyvale, CA) DSP core with a range of development and debugging tools.

The CDMA-specific data protocols for packet delivery lag behind the

implementation of the GPRS protocols. But, because sending wireless data over a mobile phone is a differentiating factor for wireless carriers in the mobile-phone market, CDMA- data-application support will be available soon. The current CDMA standard, IS-95A, includes the first service with 14.4-kbps circuit-switched connections for data and fax. A packet-switched service with a 14.4-kbps data rate should be available this year. The IS-95B-standard

data service is eyeing 64-kbps bidirectional data, but information on availability is sparse.

SMS is another option of standard chip sets for PCS mobile phones. The GSM standard includes provisions for

**TABLE 3—REPRESENTATIVE TWO-WAY MOBILE WIRELESS-SERVICE PROVIDERS**

Service provider	Features	Coverage	Data rates (kbps)	Radio network
Ardis Circle No. 329	Offers packet-data radio services with 14-sec guaranteed latency; 95% network availability; and deep in-building coverage	425 US metro areas	19.2	DataTAC
AT&T PocketNet Circle No. 330	Uses CDPD Internet Protocol for wireless access to the Internet from a Windows CE end-user device; the AT&T Wireless Data Developer program uses handheld-device markup language (HDML) to develop applications	99.9% of US metro areas	19.2	Cellular Digital Packet Data
DTS Wireless Zap-It Circle No. 331	Receiving and responding service for e-mail, faxes, and phone messages to handheld PCs or laptops; stores messages if end-user device is off; for Windows 95, 3.1, and CE and HP palmtop or LX-series equipment	92% of US urban business areas	8	Mobitex
Metricom Utilnet	Frequency-hopping spread-spectrum packet radio in a connectionless mesh network of intelligent nodes; each radio is both an end-user device and a repeater; applications are industrial remote telemetry and distributed control; 902 to 928 MHz	Local, if you have it installed	9.6	Microcell using unlicensed band
Ricochet Circle No. 332	Same as Utilnet, except it provides wireless access to e-mail, Internet, and corporate LANs for a service fee. You can rent, lease, or buy a modem radio; constructed from a mesh pattern of radios every quarter- to half-mile; 902 to 928 MHz	San Francisco, Seattle, and Washington; mesh of microcell radios	28.8	Microcell using unlicensed band
Nextel iDEN Circle No. 333	Digital-cellularlike service that combines voice, dispatch, short messaging, and future packet data; Integrated Digital Enhanced Network increases cellular capacity and performance with vector-sum excited linear predictors (VSELPs), QAM, and TDMA	Most US urban centers	9.6	Integrated Digital Enhanced Network
RAM Mobile Data Circle No. 334	Offers packet-radio service in partnership with BellSouth (Atlanta); supports wireless-Internet and wireless-Internet Protocol applications	93% of US urban business areas	8	Mobitex
Unwired Planet Link Platform Circle No. 335	Offers open communications platform, including browser, gateway, and HDML to carriers, network operators, and service providers for access to the Internet; the communications platform is network- and device-independent	Depends on carrier	Depends on network	Depends on carrier

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short messaging that essentially replace technology for paging and are useful in such transaction services as banking. Short messages can be 160 characters and use the same channel as voice calls. This service is a low-cost way to add paging to a product that already has built-in two-way voice capability. Lucent's Sceptre chip set includes SMS capability.

## Cheap end-user devices

The cheapest and most common wireless-data end-user devices are paging units. These units efficiently use the allocated spectrum for sending

one-way data to one or more recipients. The units also offer complete coverage in the United States and nearly every other country. Paging has evolved from tone-only notification to short alphanumeric messages to two-way paging. Paging's user-comfort level gives it an advantage over other means of data communications. Paging is also enjoying renewed interest because of the increasing use of push technology.

The economics of using paging in your design depends on how much data you have to send and what latencies your design can tolerate. The public paging carriers charge fees for using

their networks; these fees depend on the geographic area that the network covers, the number of characters in a message, and the time of day. Most paging services allow you to send as many as 10,000 characters per month for a basic-service charge. If you use short messages at off-peak hours, simple paging is an economical way to wirelessly distribute data.

Paging latency varies from low to unpredictable. A message's latency depends on the paging protocol and the amount of queued traffic in the system. For example, the Flex protocol from Motorola gives an application

## REPRESENTATIVE WIRELESS-DATA VENDORS, ORGANIZATIONS, AND SERVICE PROVIDERS

For more information on products such as those described in this article, circle the appropriate numbers on the Information Retrieval Service card, or use *EDN's* Express Request service. When you contact any of the following manufacturers directly, please let them know you read about their products in *EDN*.

## Wireless-data IC vendors

AKM Semiconductor Inc  
San Jose, CA  
1-408-436-8580  
www.akm.com  
Circle No. 311

Analog Devices Inc  
Wilmington, MA  
1-617-937-1428  
www.analog.com  
Circle No. 312

GEC Plessey  
Scotts Valley, CA  
1-408-439-6049  
Circle No. 313

LSI Logic  
Milpitas, CA  
1-800-574-4286  
Circle No. 314

Lucent Technologies  
Berkeley Heights, NJ  
1-800-372-2447  
www.lucent.com  
Circle No. 315

Motorola  
Phoenix, AZ  
1-800-521-6274  
www.mot.com/sps  
Circle No. 316

Philips Semiconductors  
Sunnyvale, CA  
1-408-991-2000  
www.philips.com  
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Texas Instruments  
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www.ti.com  
Circle No. 321

VLSI Technology  
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1-408-922-5250  
www.vlsi.com  
Circle No. 322

Standards and trade organizations for wireless data

Cellular Telecommunications Industry Association  
Washington, DC  
1-202-785-0081  
www.wow-com.com  
Circle No. 323

Globalstar  
San Jose, CA  
1-408-933-4000  
www.globalstar.com  
Circle No. 324

GSM North America  
Alexandria, VA  
1-703-799-7383  
www.pcsdata.com/gsm  
Circle No. 325

Narrowband Sockets  
http://developer.intel.com/ial/nbs/  
Circle No. 326

Wireless Application Protocol Forum  
1-212-685-4030  
www.xwap.com  
Circle No. 327

Radio vendor  
World Wireless Communications  
Salt Lake City, UT  
1-888-992-9924  
www.worldwireless.com  
Circle No. 328

Wireless-data-service providers

Ardis  
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1-800-494-1732  
www.ardis.com  
Circle No. 329

AT&T Wireless Services  
Kirkland, WA  
1-425-803-4901  
www.att.com/wireless/data/  
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Woodbridge, NJ  
1-908-602-1144  
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## WIDE-AREA WIRELESS DATA

developer the option of controlling latency by setting a "collapse value," the time between the pager's wake-ups. When the collapse value is zero, the pager "wakes up" to check for messages every 1.87 sec. By adjusting the collapse value, a developer can adjust the wake-up cycle to as many as 4 minutes and can thereby conserve power by keeping the pager in sleep mode longer. This sleep mode increases latency, and latency is still unpredictable, because the paging system's limited bandwidth could block a message in the queue at the transmission station and miss the wake-up-cycle timing.

Adding paging to a design is as simple as adding a receiver module to an end-user device that already incorporates a  $\mu$ P. Motorola's Flex messaging module acts as the receiver module (**Figure 3**). The Flex module gives the 3Com's (San Jose, CA) PalmPilot pager card its wireless connection. Flex includes an RF receiver and Flex decoder circuits. You can embed Flex into products to facilitate wireless remote-control applications.

Several features make Flex attractive for incorporating low-cost, one-way wireless data. The Flex suite of application protocols enables end-to-end applications. This suite provides efficient messaging, basic message security, and message-routing capabilities. Power consumption is a concern in mobile units, and Flex is a power miser. The Flex module has an average current drain of less than 1 mA from a 3V source, based on an operating profile for message length, message frequency, and wake-up duty cycle. In addition, the module provides 16 short and eight long electronic addresses that are configurable over the air.

Designing in a two-way radio module can give you more features than a paging module in an end-user device. Many companies, such as World Wireless Communications, offer radio modules. The company's LSDR 100 is a direct-sequence, spread-spectrum radio with an RS-232C interface. Applications for the LSDR 100 include telemetry, remote data collection, monitoring, and tracking. Coverage for each radio is more than 35 miles for line-of-sight distance. The LSDR 100 operates

in the 902- to 932-MHz band with a 4.8-kbps data rate. The module measures 5.75 $\times$ 4.5 $\times$ 1.5 in. and comes with indoor or outdoor enclosures.

## Wireless-data-service providers

When choosing a wireless-service provider (**Table 3**), you can invest in your own private network to serve this function, or you can contract with a service provider. Service providers offer protocols to connect your applications to the wireless network. Offerings vary, but most include a messaging service, Internet gateways, and application development for vertical markets. You should consider coverage area, data rates, and network availability. Paging carriers and satellite-service providers also offer services similar to those of the vendors in **Table 3**.

Packet-data wireless-service providers have long struggled to find a killer application to grow their subscriber base. Industry experts originally thought that packet-data wireless service had widespread applications in vertical markets such as field sales. However, most recent market growth has been in wireless e-mail access through gateways to the Internet. Providers such as Ardis, RAM, AT&T's PocketNet, and DTS Wireless' Zap-It offer these gateway services.

Wireless-network providers also provide development programs, such as Ardis' Wireless Software Developer Program. This program provides the tools to get your application up and running on the wireless network. The program also offers hints on how to efficiently use the wireless network's limited bandwidth, how to keep forms and templates on the end-user device, and how to use matching codes rather than transmitting long descriptions. Also, the program's guide explains how to analyze the trade-offs between host and peer-to-peer routing in the network and how to decide which approach is best for your application.

The Metricom Ricochet network offers low-power microcell-radio technology to the mass-consumer market. Metricom is a service provider, but, because the right network technology did not exist, Metricom designed and implemented its own. Its system uses

microcells on utility poles to connect pedestrian and stationary modems to the network. Metricom locates the microcells every quarter- and half-mile in a mesh pattern. The microcells relay traffic to wired access stations that are about 20 miles apart. This network provides Internet access with throughput as high as 28.8 kbps. Many subscribers choose this network as an alternative to a V.34 modem on a telephone line. Metricom is working on increasing the throughput to match the integrated-services digital network at 128 kbps by upgrading the modulation scheme in its network.

Many more options exist for network technologies, end-user devices, and service providers. With the innovations in this fast-growing field and the cheaper cost of systems, engineers can now consider applications for wireless-data communications that were previously unfeasible. By weighing the trade-offs in coverage, data rates, and system costs, you can find the right mix for wireless-data access to meet your application requirements. EDN

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