



Get Wireless: A Mobile Technology Spectrum

Prathima Agrawal and Cormac J. Sreenan

Mobile computing applications allow anytime, anywhere access to the Internet and corporate intranets.

Tired of carrying a laptop, a PDA, a phone, and a pager when you travel? Tired of using a separate device for every function, each one differing in terms of capability, price, weight, size, and usability? Then you're tired of dealing with the large spectrum of offerings the immature mobile technology market offers.

What you're experiencing are the trade-offs device designers are making to accommodate

different user, application, size, and power constraints. These gadgets are the result of very recent advancements in computing, communications, data networking, hardware, VLSI (very large scale integration) chips, and battery technology.

Every day now we hear about some new portable gadget for people on the go. Worldwide, the demand for cellular and personal communication is exploding: Strategis Group projects that there will be 430 million such subscribers by the end of this year.

Wireless voice offerings are now common; the rush these days is for wireless data services. Traveling professionals are demanding anytime, anywhere access to horizontal applications such as e-mail, Web browsers, remote login, and file transfer. With the increasing applications for mobile users, it seems just about every business can benefit from wireless technology.

Because there are so many variables—dependability, capabilities, pricing, popularity, and so on—it's hard to predict where the mobile technology market is going. Some designers think computing

and communications will merge into one device; others think there will be even more kinds of specialized devices.

PORTABLE PLUS WIRELESS EQUALS MOBILE

For several reasons, the market for wireless data services has grown at a much slower rate than wireless voice. Until recently, portable data devices were bulky, required heavy batteries, and didn't have integrated networking. Wireless services have also had to contend with narrow bandwidths, high access latency, and frequent disconnection. Added to this were inadequate coverage, expensive services, and perceived security problems. Finally, few applications were specifically designed with mobility in mind.

New mobile technologies address these problems, making wireless data transmission an attractive alternative for individuals and enterprises. The next few years will see wireless data networks come into their own. Next year, the market for wireless data networks is predicted to grow to six to eight million users with seven percent of the total wireless revenues. In fact, wireless data service is projected to be a multibillion-dollar market within five years. The combination of portable gadgets and wireless data services provides exciting opportunities for mobile computing applications.

Inside

Resources

**Wireless Networking Primer
Update on Third-Generation
Wireless**

Spectrum of devices

At one extreme are laptops. Some people believe the future of laptops involves miniaturization with loss of functionality. A more appealing direction is smartphone technology. Smartphones are very small devices that provide less functionality than general-purpose laptops. Smartphones are either voice- or information-centric.

Voice-centric devices, such as those used with the AT&T PocketNet Service, combine voice telephony functions with access to select information services such as e-mail, personal calendars, and news updates. These devices have little local storage, instead relying on remote servers to provide reliable storage and ubiquitous service access.

Information-centric devices combine voice telephony with PDA-style functionality. An example is Qualcomm's pdQ smartphone, which incorporates the Palm Computing platform. pdQ maintains local information for address books, calendars, and so on, and it allows you to install other applications such as Web browsers. Because they are local to the device, you can access some functions such as address books without connectivity.

These two devices illustrate the trade-off between infrastructure dependence and device complexity. A device like the pdQ smartphone can provide limited functionality even without access to the wired infrastructure, but only at the cost of additional device resources and complexity.

Power issues

Power issues also heavily influence device design because battery technology is advancing at a much slower pace than computing and communications. Mobile devices may need to efficiently process multimedia information, perform speech recognition, allow wireless communication, and accommodate high-resolution displays. The desire to support these functions implies an increased demand for power.

One way to reduce power consumption is to off-load many functions to wired infrastructure servers. This reduces processing and storage in the device itself, but again it creates dependence on accessing the infrastructure.

Power-conscious network protocols—currently an active research topic—can also lead to reduced power consumption.

Operating systems

Finally, operating systems are another important issue that affects device design. A mobile OS's critical requirements are interoperability, portability, scalability, heterogeneous processor support, user interface quality, support for real-time applications

Resources

Online

- <http://www.bluetooth.com>: Provides up-to-date information on Bluetooth.
- <http://www.cdpd.org>: A good starting point for finding other wireless data sites.
- <http://www.comsoc.org/pubs/pcm/index.html>: Home page for *IEEE Personal Communications* magazine.
- <http://www.telecomresearch.com>: Has tutorials and other wireless resources.
- <http://www.wapforum.org>: Describes the activities of the Wireless Application Forum.
- <http://www.wirelessdata.org>: The Wireless Data Forum, an excellent source for market projections, service coverage maps, and more.

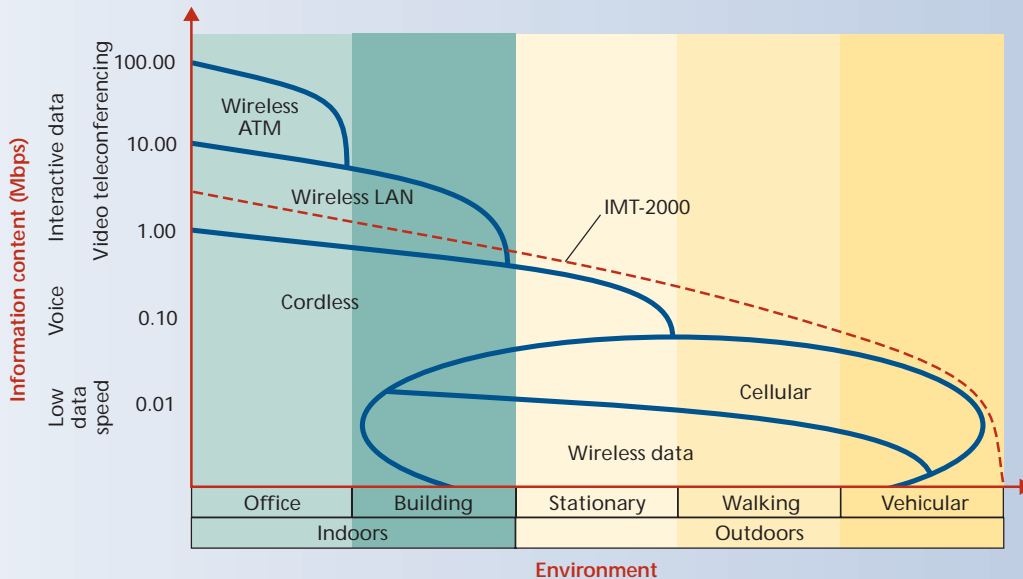
Books

- *Wireless Personal Communications*, D.J. Goodman, Addison Wesley, 1997: Describes the design of today's cellular voice and PCS systems.
- *Mobile IP: Design Principles and Practices*, C.E. Perkins et al., Addison Wesley, 1997: The definitive book on mobile IP, written by a key contributor to the IETF standard.

Articles

- "Advances in Wireless Terminals," P. Lettieri and M.B. Srivastava, *IEEE Personal Comm.*, Feb. 1999, pp. 6-18: Addresses the design of future wireless terminals, including energy efficiency and reconfiguration.
- "Design and Evaluation of a Platform for Mobile Packet Telephony," S. Goel et al., *Proc. IEEE Int'l Workshop on Network and Operating System Support for Digital Audio and Video (NOSSDAV)*, IEEE Press, Piscataway, N.J., 1998, pp. 71-81: Explores issues for supporting integrated voice and data on a packet wireless network.
- "Energy Efficient Protocols," P. Agrawal, *Proc. IEEE Int'l Symp. Personal, Indoor and Mobile Radio Comm.*, IEEE Press, Piscataway, N.J., 1998: Provides insight into the design of power-conscious wireless protocols.
- "SWAN: A Mobile Multimedia Wireless Network," P. Agrawal et al., *IEEE Personal Comm.*, Apr. 1996, pp. 18-33: Presents a wireless multimedia system based in ATM networking technology.
- "Third Generation Mobile Systems in Europe," *IEEE Personal Comm.*, special issue, Apr. 1998.
- "Vendors Battle over Mobile-OS Market," G. Lawton, *Computer*, Feb. 1999, pp. 13-15: A survey of the competing alternatives for mobile device operating systems.
- "Wideband CDMA," *IEEE Comm.*, special issue, Sept. 1998.

Figure 1. Wireless communications are either high-tier or low-tier depending on the allowed movement speed and transmission power levels.



like voice communication, and the ability to be networked to PCs and LANs. These issues need to be addressed within the constraints imposed by devices that are designed to be mobile and wireless. A number of OSs with small memory and storage requirements have emerged lately to support computing-related functions.

APPLICATION DESIGN

Designing a mobile computing application presents several challenges. The two main ones concern the nature of handheld devices and the nature of remote transmissions.

Portable devices are resource-constrained compared to desktop computers—the screens are smaller, and many devices don't have keyboards and other conventional I/O modes.

One solution is the Handheld Device Markup Language, a variant of the HTML language used to define Web pages. HDML specifically supports Web browsing using handheld devices with small screens. The Wireless Application Protocol Forum, an industry association comprising over 90 members, is defining a comprehensive platform for Web access that supports heterogeneous handheld devices and a wide variety of wireless networks.

Because it is mobile, wireless naturally has to contend with high error rates, variable bandwidths, and frequent disconnects (voluntary and involuntary). Therefore, mechanisms for dealing with disconnects, adapting to the current environment, and synchronizing with hosts on the wired network are important application design elements. User

mobility creates a whole new class of applications that use location and other context information. Examples include delivering traffic reports and local weather updates.

ACCESSING THE ETHER

Of course, wireless communication is the key ingredient that turns a portable device into a mobile communicator.

Mobile communication systems are either high- or low-tier, depending on the allowed movement speed and transmission power levels.

High-tier mobile phone systems allow communication while you are moving quickly, as in a train or automobile. These systems use high-power radio antennas mounted on outdoor towers. A single antenna tower can cover tens of miles in sparsely populated areas. High-tier data services give mobile users wide- or metropolitan-area Internet access and short-messaging services.

Low-tier systems typically support movement only at walking speeds, and their antennas have significantly lower power than high-tier antennas. Low-tier antennas are often located indoors, and they only cover areas up to a few hundred yards. Low-tier data services are used to provide indoor access to corporate intranets.

Figure 1 illustrates the relationships among the various wireless solutions.

FIRST-GENERATION WIRELESS

In North America, the Advanced Mobile Phone System is the dominant first-generation digital network. AMPS

implements the Cellular Digital Packet Data overlay network. CDPD offers a 19.2-Kbps raw data rate that all data users in a cell coverage area share.

Instead of using a dedicated circuit for data transmissions, CDPD uses idle periods on regular voice channels to provide a packet-switched service. This is a more efficient use of the spectrum for data traffic, which, unlike voice, has variable bandwidth requirements.

Service access requires a special CDPD wireless modem, either a PC card in a laptop or integrated into a personal communicator. You can use the IP protocol to access the Internet to browse the Web, process e-mail, file reports, and so on.

Many carriers now offer CDPD wireless Internet access service in metropolitan areas throughout North America. In areas without CDPD coverage, the modem can use CS-CDPD, a circuit-switched operation mode, thus providing seamless mobility. CDPD customers can usually opt to be billed by the Kbyte or on a flat-rate basis, depending on their expected usage patterns.

SECOND-GENERATION WIRELESS

Second-generation wireless systems use digital technology and offer higher data rates, increased reliability, and better security.

There are three personal communication services standards. The Global System for Mobile Communications (GSM) is a pan-European digital PCS (personal communications service) standard that is currently operating in more than 200 countries and that is gaining popularity in the US.

The two North American PCS standards are IS-136, which uses TDMA (time division multiple access), and IS-95, which uses CDMA (code division multiple access). See the "Wireless Networking Primer" sidebar for a brief explanation of TDMA and CDMA.

PCS systems also provide a short messaging service for applications such as paging and emergency broadcasts. GSM and IS-136 networks offer circuit-switched data access based on a single channel at 9.6 Kbps. To use this service, you attach your laptop to a PCS phone port via a serial cable. Future plans are to provide a high-speed, circuit-switched data service that combines multiple channels to provide service at 38.4 Kbps.

GSM also plans to provide the Generalized Packet Radio Service, a packet-switched data service that should be available next year. With initial

Wireless Networking Primer

It's not easy to get a handle on wireless technology. There are many competing technologies and several underlying issues, ranging from physical-layer propagation characteristics to finding the location of devices. Here are a few key things you need to know about wireless.

The electromagnetic spectrum is a scarce resource that must be shared among different technologies and services, and its use is regulated by national and international agreements.

In North America, wireless voice and data networks operate in the radio frequency (RF) bands ranging from about 800 MHz up to 2.4 GHz. Voice is carried in the licensed 800-MHz cellular and 1.9-MHz PCS bands. Wireless LANs and cordless phone systems operate in unlicensed spectrum. The higher spectrum in the 5-GHz band has been allocated for emerging unlicensed high-speed data services.

Various access techniques govern how several co-located transmitters share time/frequency space. The two most common approaches are time division multiple access (TDMA) and code division multiple access (CDMA).

TDMA (<http://www.caasd.org/papers/MTR/94W035/index.html>) divides space into a sequence of time slots. It typically is used in a hybrid fashion with frequency division multiple access (FDMA), so that each frequency supports multiple channels. IS-136 and GSM use TDMA.

With CDMA (<http://www.cdma.com/cdmatechnologies/cdma.html>), multiple transmitters occupy the same time/frequency space. Transmitted data is spread over this space, and each call is assigned a unique sequence code.

Packet radio systems are usually based on dynamic time slot assignment. The IEEE 802.11 standard uses carrier sense multiple access (CSMA), which is similar to having a wireless Ethernet protocol.

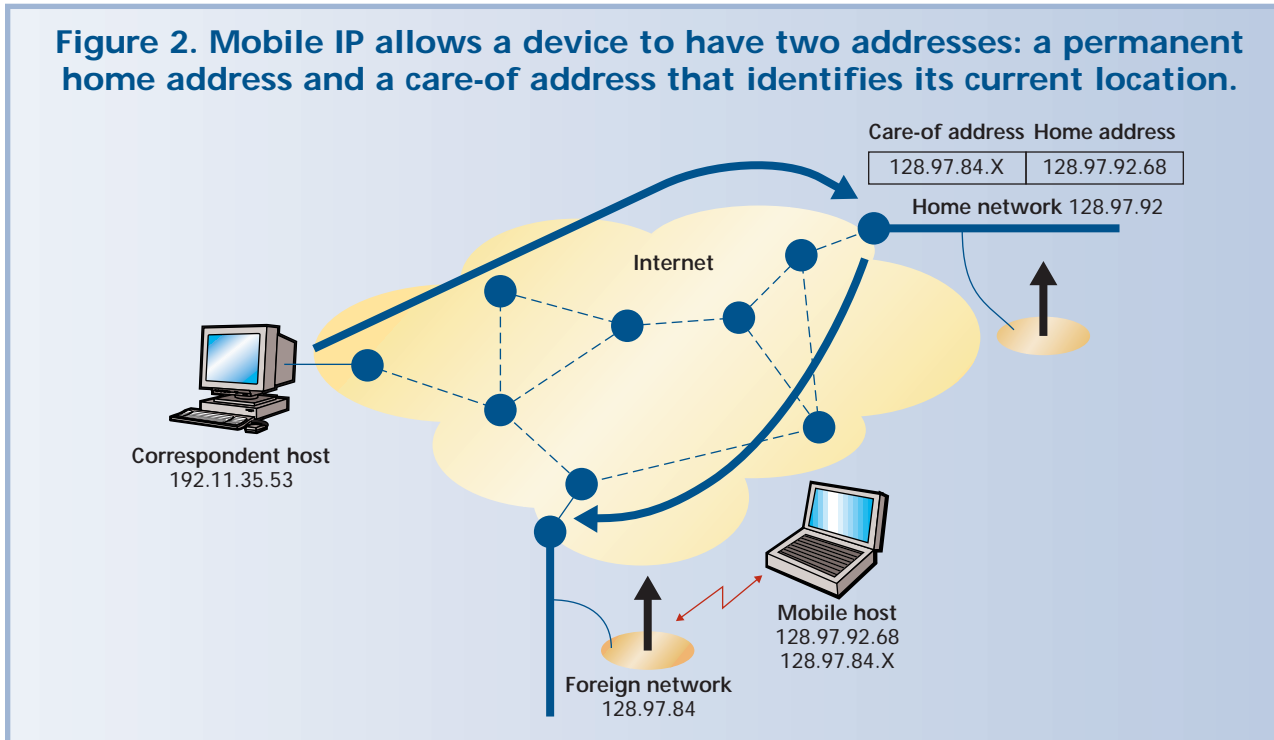
Cellular systems are designed to replace a single high-power transmitter that would cover an entire service area with lots of lower-power transmitters (base stations), each covering a fraction of the service area (the cell).

Cellular systems address spectrum congestion and capacity problems by reusing frequencies in cells that are far apart. As a mobile device moves from one cell to another, it is handed off to the new cell and service to the mobile device continues uninterrupted.

More recently, ad hoc or infrastructureless data communications networks have become popular. Mobile devices can use these networks to correspond directly without using base stations. These networks are popular in situations where deploying a cellular infrastructure isn't practical, such as on the battlefield and for personal area networks.



Figure 2. Mobile IP allows a device to have two addresses: a permanent home address and a care-of address that identifies its current location.



speeds of more than 100 Kbps, GPRS will be a significant leap forward in bandwidths and should open up markets for new applications, including multimedia. The longer term plan for GPRS is to provide over-300-Kbps service, an initiative under way as part of EDGE—Enhanced Data Rates for GSM Evolution.

Wide-area wireless

Several companies currently provide packet-switched data services in metropolitan areas and large campus environments. For example, Metricom offers its unlimited-use Ricochet wireless Internet access service at speeds up to 28.8 Kbps in several US metropolitan areas and airports. To use Ricochet, you attach a wireless modem to the serial port on your laptop computer or PDA. Ricochet’s network topology is a mesh of repeating packet radios consisting of microcell base stations mounted on street lampposts. These microcells use a wireless connection to wired access points to connect with the Internet, corporate intranets, and a telephone modem bank. The system uses data encryption and secure transmission techniques to ensure data privacy. Metricom is upgrading its network to offer 128-Kbps bandwidths.

Local-area wireless

There are several solutions for wireless data access within a building or small campus. The wireless LAN market has been increasing steadily over the past several years, providing a lower-bandwidth alternative to wired LANs.

Today’s wireless LANs typically operate at raw data rates of about 2 Mbps, but rates up to 20 Mbps will soon be available. Examples include Lucent’s WaveLAN and Proxim’s Symphony network. These systems are compatible with the IEEE 802.11 wireless LANs standard, which specifies an Ethernet protocol for shared wireless access. Laptops equipped with modems can communicate directly with each other or via an Ethernet-attached access point.

Digital cordless telephone systems are an alternative short-range access technology. A popular example is the Digital European Cordless Telecommunications system. These systems have the advantage of providing both voice and data in a single system, but the data rates typically are lower than for wireless LANs.

Mobile IP

Use of the IP protocol in mobile devices raises a sticky problem. The Internet was designed to route packets to stationary hosts. In fact, an IP address identifies both a destination computer and the subnet it is attached to. Internet routers use each packet’s destination IP address to forward it hop by hop toward the subnet’s target router.

This model breaks when you move your mobile device to an area that belongs to a different subnet because the packets will still be delivered to the original subnet. Mobile IP, in short, requires mobile-aware devices.

The IETF’s Mobile IP, which is already available for Unix and Microsoft Windows NT systems, seeks to address this problem.

Mobile IP allows a mobile device to have two IP addresses: a permanent home address and a care-of address, which identifies a device's current location. Figure 2 shows how Mobile IP works: A home agent runs on the device's home network. When the device enters a foreign network, it registers a care-of address with its home agent. The home agent then acts as a proxy, accepting packets and forwarding them to the device's current location.

The IETF has been working for many years to iron out other Mobile IP issues. For example, what's to prevent someone from stealing a transmission by registering a false IP address with the home agent? How can we deal with the inefficiencies caused by Mobile IP's routing structure, if every packet destined for a mobile host must travel first to its home network? An extreme case of this triangular routing might happen when a user from New York takes his laptop to San Francisco only to find that data coming from another San Francisco computer is corresponding with his laptop via New York! The IETF has defined a Mobile IP extension that avoids triangular routing by maintaining a cache of care-of addresses at correspondent hosts.

THIRD-GENERATION WIRELESS

Improved devices and widening bandwidths are continually changing the mobile computing market. Several new technologies will transform it even further. Work is being done in Europe and North America to define third-generation wireless systems. By 2005, third-generation wireless will use heterogeneous air interfaces to provide seamless global broadband and multimedia communications. The "Update on Third-Generation Wireless" sidebar provides more information about these efforts.

At the other extreme, Bluetooth, a cooperative effort between telecommunications and computer industry leaders, is developing low-power wireless technology for short-range communications. Bluetooth technology will, for example, let your laptop communicate via an adjacent PCS telephone. Initial Bluetooth products enabling applications such as personal area networks and cordless desktops should be available next year.

With significant advances in wireless communications and the expanding capabilities of portable devices, the stage is set to enable anytime, anywhere, any form access to the Internet. And just around the corner is the third generation of wireless networking, which will project wireless multimedia into the mainstream and have a deep and lasting impact on the way people communicate. ■

Prathima Agrawal is a chief scientist and assistant vice president in the Internet Architecture Research Laboratory at Telcordia Technologies Inc. (formerly Bellcore) in Morristown, New Jersey. Contact her at pagrawal@research.telcordia.com.

Cormac J. Sreenan is a principal technical staff member at AT&T Labs-Research in Florham Park, New Jersey. Contact him at cjs@research.att.com.

Update on Third-Generation Wireless

The International Telecommunication Union (ITU) is developing International Mobile Telecommunications-2000 (IMT-2000), a flexible standard for wireless access to the global telecommunication infrastructure. IMT-2000 is a third-generation framework, designed to provide seamless global access to an array of advanced multimedia services.

The ITU is developing IMT-2000 as a "family of systems" that provides services globally. The European Telecommunication Standards Institute (ETSI) is coordinating the Universal Mobile Telecommunication System (UMTS), Europe's third-generation contribution.

IMT-2000 is built around an infrastructure based in the 2-GHz frequency band. It serves both mobile and fixed users through public and private networks. Its goal is to unify today's diverse systems into a common, flexible radio

infrastructure that carries voice, image, video, music, and sensor data.

The objective of third-generation wireless is to provide broadband and multimedia services with quality comparable to fixed networks. Third-generation systems will support up to 144 Kbps in all environments with full mobility, 384 Kbps for pedestrian speeds outdoors, and up to 2 Mbps indoors.

In 1998, the ITU accepted IMT-2000 radio interface proposals, and in March 1999 it agreed to the key characteristics for such interfaces. Final recommendations are expected by the end of this year. Wideband CDMA is a key IMT-2000 radio technology that offers high-bandwidth packet communications using a CDMA version with improved spreading capabilities.

Japan and Korea plan to introduce third-generation systems in 2000. Europe projects initial UMTS operation in 2002, with full-fledged operation by 2005. In the US, limited introduction of third-generation systems is anticipated between 2003 and 2005. Exact deployment dates will depend on market demand for third-generation services and other deployment issues.

