Recent Advances in Wireless Networking

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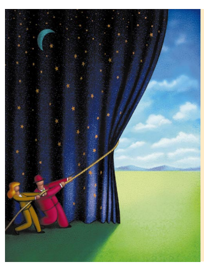
After discussing advances in wired networking in a previous column ("Recent Advances in Wired Networking," *Computer*, April 2000, pp. 107-109), I now turn to advances in wireless networking. Wireless networks can include everything from cellular, personal communications system (PCS), and Group System for Mobile communications (GSM) networks to wireless LANs, satellite-based networks, and fixed wireless networks. Many of these technologies have experienced significant growth lately because of an increasingly mobile workforce and accelerating user acceptance.

Although voice and short messaging drove the early successes of wireless networks, data and more sophisticated applications are driving advancements today. Significant progress has also been made in middleware development and standardization. These factors—along with demand for higher bandwidth and global roaming—will continue to push the standardization and the near-future deployment of third-generation wireless networks using terrestrial and satellite components.

ISSUES IN MOBILE AND WIRELESS NETWORKS

Mobile users do not necessarily need to use wireless interfaces, and wireless interfaces do not necessarily support mobility. Therefore, mobile and wireless systems are not the same even if they overlap considerably. Mobile networks provide support for routing functions (to maintain communication with mobility) and location management functions (to keep track of the location). Wireless networks provide wireless interfaces to users (both mobile and stationary) by supporting bandwidth allocation and error-control functions. Several issues can arise when they are put together, including optimal use of low bandwidth channels, management of large bit error rates, application-level quality-of-service support, increased security concerns, and equipment failure.



The future for wireless networking is very bright indeed, especially if advances continue to support more sophisticated applications.

Cellular, PCS, and GSM systems

With 300 million worldwide in 1999, the total number of cellular and PCS subscribers is expected to reach one billion by 2004. Two percent of the US population uses a cell phone as the primary telephone access, and 10 percent of all calls in the US involve cellular, PCS, or GSM phones. Because of the roaming agreements among carriers, nationwide roaming already exists in the US. In many European countries, the use of GSM has allowed cross-country roaming. However, the dream of global roaming hasn't yet been realized because there are too many of these incompatible standards.

For example, US standards use Frequency Division Multiple Access (in Advanced Mobile Phone System, the analog cellular standard), Time Division Multiple Access (in PCS), and Code Division Multiple Access (IS-95), while GSM uses TDMA/FDMA over different frequencies. These differences (listed in Table 1) have made agreeing on third-generation standards a difficult task. Once the industry deploys third-generation networks worldwide in the next two to three years, global roaming will become a reality. For the time being, mobile users can use multifunction and multiband phones to roam across several continents.

Wireless LANs

Unlike cellular networks with allocated channels (frequencies), users in WLANs have to share frequencies, which may eventually lead to collisions. The choice of frequency depends on whether microwave, spread-spectrum, or infrared communication will be used. Interference and security depend on the type of communications method used in the WLAN.

The two wireless standards are IEEE 802.11 and Hiperlan. The 802.11 standard supports 1 Mbps (11 Mbps in a future version) while Hiperlan can be used to support 23.5-Mbps channel rates. The 802.11 standard also supports several choices of physical medium such as spread spectrum and infrared while Hiperlan only allows for spread spectrum.

Many universities and companies are encouraging the use of IEEE 802.11-based LANs for accessing campus computing systems and the Internet. Another emerging wireless LAN standard is Hiperlan2, which is being standardized by ETSI

Table 1. Access protocols and major cellular/PCS systems.

System (starting year)	Access protocol	Frequency (MHz)	Compatibility with other existing systems	Services
AMPS (1983) Cellular	Frequency Division Multiple Access/Frequency Division Duplexing	824-894	N/A	Voice, data using modem
GSM (1990) Cellular/PCS	Time Division Multiple Access/ Frequency Division Multiple Access/ Frequency Division Duplexing	890-960	N/A	Voice, data, paging
Interim Standard-54 (IS-54) United States Digital Cellular (1991) Cellular	Time Division Multiple Access/ Frequency Division Multiple Access/ Frequency Division Duplexing	824-894	With AMPS (dual mode phones are standard)	Voice, data, paging
Interim Standard-95 (IS-95) (1993) Cellular/PCS	Code Division Multiple Access	824-894 1850-1980	With AMPS (dual mode phones are standard)	Voice, data, paging
Digital Communications Systems 1900 (DCS-1900) (1994) PCS	Time Division Multiple Access/ Frequency Division Multiple Access/ Frequency Division Duplexing	1840-1990	With GSM (but frequencies are different)	Voice, data, paging
Universal Mobile Telecommunications Systems (UMTS)/International Mobile Telecommunications-2000 (IMT-2000) (2000 or later) third generation	One of wideband CDMA, CDMA2000 or TDMA	1885-2025 2100-2200	CDMA2000 for backward compatibility with IS-95 TDMA for backward compatibility with GSM	Multimedia, video, voice, data

(European Telecommunications Standard Institute) and expected to be ready by 2000. An exciting aspect of Hiperlan2 is that it provides for use of connections that offer different quality of service for different applications. Hiperlan2 uses time-division multiplexing of unicast, multicast, and broadcast connections.

Satellite-based systems

Many satellite-based networks using low, medium, or geosynchronous earth orbits (LEO, MEO, and GEO) have started to provide commercial service. However, due to the high initial cost and per-minute charges, the number of customers for satellite-based mobile communications remain a small minority among a much larger number of wireless users.

For example, Iridium had to file for bankruptcy due to the lack of customers signed up for its satellite phone service. The service has been discontinued after the company was not able to find a financial backer to cover expenses. Several lessons should be learned from the failure of such large-scale and technologically advanced projects. I believe that the market for such satellite-based mobile services does exist in many countries and in areas with no (or poor) cellular/PCS service. But new pricing models may be necessary to create wider acceptance.

Fixed wireless systems

Unlike the mobile version, the fixed wireless systems support little or no mobility of users. One example is wireless local loops (WLLs) that are being designed to support regular phone service and high-speed Internet access. These loops allow long-distance carriers to bypass the existing wired local loops owned by local phone carriers (which saves access charges that can add up to $20 billion/year in the US alone).

In the developing world where laying millions of miles of copper is impractical, WLLs can provide phone and low-speed data transfer. Although several technological options exist to support WLL, an interesting choice is the use of Local Multipoint Distribution Systems (LMDS) for high bandwidth (tens of megabits per second) for a large number of users. LMDS can support point-to-multipoint applications but requires direct line-of-sight because it uses the 28-to-31-GHz band. Recently the FCC allocated 1.3 GHz of spectrum to several hundred LMDS providers.

THIRD-GENERATION WIRELESS NETWORKS

Recently, the International Telecommunication Union (ITU) approved a specification that includes a comprehensive set of terrestrial and satellite radio interfaces for International Mobile Telephony (IMT). These specifications offer the flexibility needed by both the satellite/terrestrial providers to design new third-generation systems and the existing operators to evolve their first- and second-generation networks into third-generation services.

As shown in Figure 1, the specification covers a set of radio interfaces for optimized performance in different radio environments. The radio specifications allow five different choices, carefully designed to help existing first- and second-generation wireless systems to work with or evolve into third-generation systems. These specifications, once standardized in 2000, will offer full interoperability and interworking of wireless networks of all three generations.

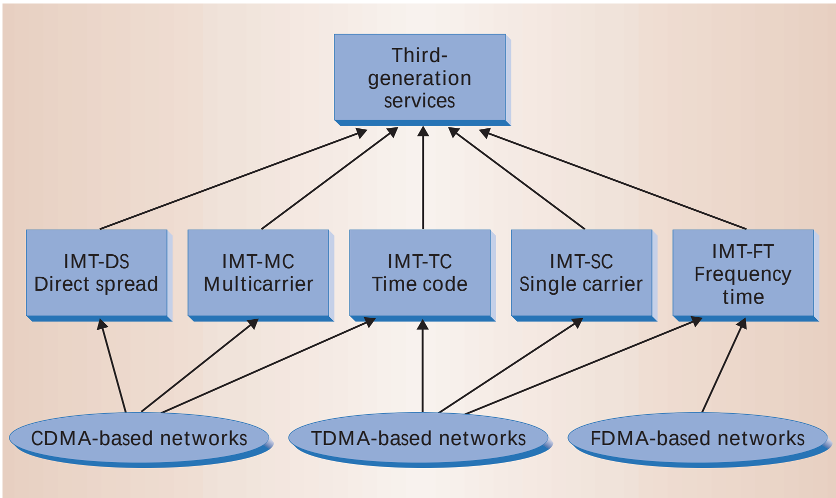


Figure 1. The approved radio specifications from IMT-2000. The five boxes represent the IMT-2000 radio interfaces. One or more of TDMA, CDMA, and FDMA can be used to provide these standardized sets of radio interfaces to a mobile user. IMT-DS radio interface is also known as Wideband CDMA and can be used by CDMA carriers to offer third-generation services. IMT-MC radio interface is commonly known as CDMA2000, another improved version of CDMA. IMT-TC is known as UTRA (UMTS Terrestrial Radio Access) Time Division Duplexing interface and also as time-division duplexed CDMA. This interface can be used by both CDMA and TDMA carriers. IMT-SC is primarily designed for TDMA-only networks. IMT-FT radio interface is also known as DECT (Digital Enhanced Cordless Telephony) and can be used by both TDMA and FDMA carriers to provide third-generation services.

Participating standards members reached a worldwide agreement on frequency allocation in 1992 by allocating 1885 to 2025 MHz and 2110 to 2200 MHz for third-generation services. Out of these bands, 1980 to 2010 MHz and 2170 to 2200 MHz sub-bands are allocated to the satellite component of IMT-2000. These specifications define how a mobile device will work irrespective of specific network or radio options chosen by operators at a specific location. IMT-2000 will also allow fixed as well as mobile wireless access, indoor and outdoor, and a diverse set of services that require widely different quality of service.

One major goal of IMT-2000 is to provide cost-effective and flexible access in developing countries and in the underdeveloped parts of developed countries. Worldwide migration to IMT-2000 is still dependent on perception of market needs, possible incentives to carriers and operators, recovery on investment made in the existing first- and second-generation wireless systems, and perceived threats to monopoly wireless carriers. One major problem that will arise in IMT-2000 implementation is the current use of some of the agreed-upon IMT bands for other existing services. Although the agreement on IMT bands was unanimous, the agreement hasn't resulted in clearing and allocation of these frequencies for third-generation services.

Additional Resources

Semi-annual wireless data from CTIA: http://www.wow-com.com
Third-generation wireless standardization: http://www.itu.org/imt
FCC E911: http://www.fcc.gov/e911
WAP forum: http://www.wapforum.com/
European Telecommunications Standards Institute (ETSI): http://www.etsi.org
Intel's GSM: http://www.gsmdata.com
Intel's PCS: http://www.pcsdata.com
Bluetooth: http://www.bluetooth.net
Hiperlan2 Global Forum: http://www.hiperlan2.com
Teledesic: http://www.teledesic.com

DEVICES AND APPLICATIONS

In addition to protocol development, wireless and mobile networking has seen many advances over the past few years, particularly in the area of devices, middleware, and new applications. Mobile middleware is the enabling layer of software used by application developers to connect their applications with different mobile networks and operating systems without having to introduce mobility awareness in the applications. The use of middleware may allow applications to run with better response times and much greater reliability.

Mobile middleware like the Wireless Application Protocol (WAP) allows the adaptation of standard Web content for transmission over wireless channels and for display over mobile devices. WAP also allows developers to build new applications irrespective of the underlying wireless access technology. Many mobile devices equipped with WAP are already in the market.

Applications

Industry analysts project that 40 percent or more of all e-commerce transactions will be initiated from handheld mobile devices by 2004. How quickly these applications are adopted by a business depends on how quickly these applications can be deployed, what their cost-value ratio is, how easy these devices are to use, and whether enough trust can be built to conduct e-commerce transactions while on the move.

The design of new wireless e-commerce applications should certainly consider the capabilities of wireless user infrastructure. Wireless middleware, which can hide the details of the underlying network to applications (while at the same time providing a uniform and easy-to-use interface) is an extremely important component in developing new mobile commerce applications.

M-commerce

Examples of m-commerce applications include mobile inventory management, a technology designed to track the location of goods, services, and possibly even people. One very interesting application would be a "rolling inventory"—which may involve multiple trucks carrying a large amount of inventory while on the move. Whenever a store needs certain items, it would locate a truck (preferably in a nearby area) and initiate a just-in-time delivery.

Another m-commerce application is proactive service management, a process that collects pertinent information about user needs and provides needed services. One such application may involve collecting information about the aging components of an automobile. Such information could be collected and analyzed by manufacturers to improve the design and manufacturing of future products.

E911 services

In the US, because of an FCC ruling, cellular and PCS carriers will be required to provide 911 centers with precise caller location information (say, within 100 meters) by 2001. The carriers are scrambling to come up with some add-on solutions to their existing networks without having to redesign everything from the ground up. Possible solutions include the use of global positioning satellite systems, several base stations for triangulation, or mixed handset-network protocols for location determination. This kind of location support, while costly, is crucial for many other applications, including the emerging intelligent transportation systems.

The future for wireless networking is very bright indeed, especially if technological advances continue to support more sophisticated applications that offer easier-to-use interfaces at reasonable prices. ✷

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