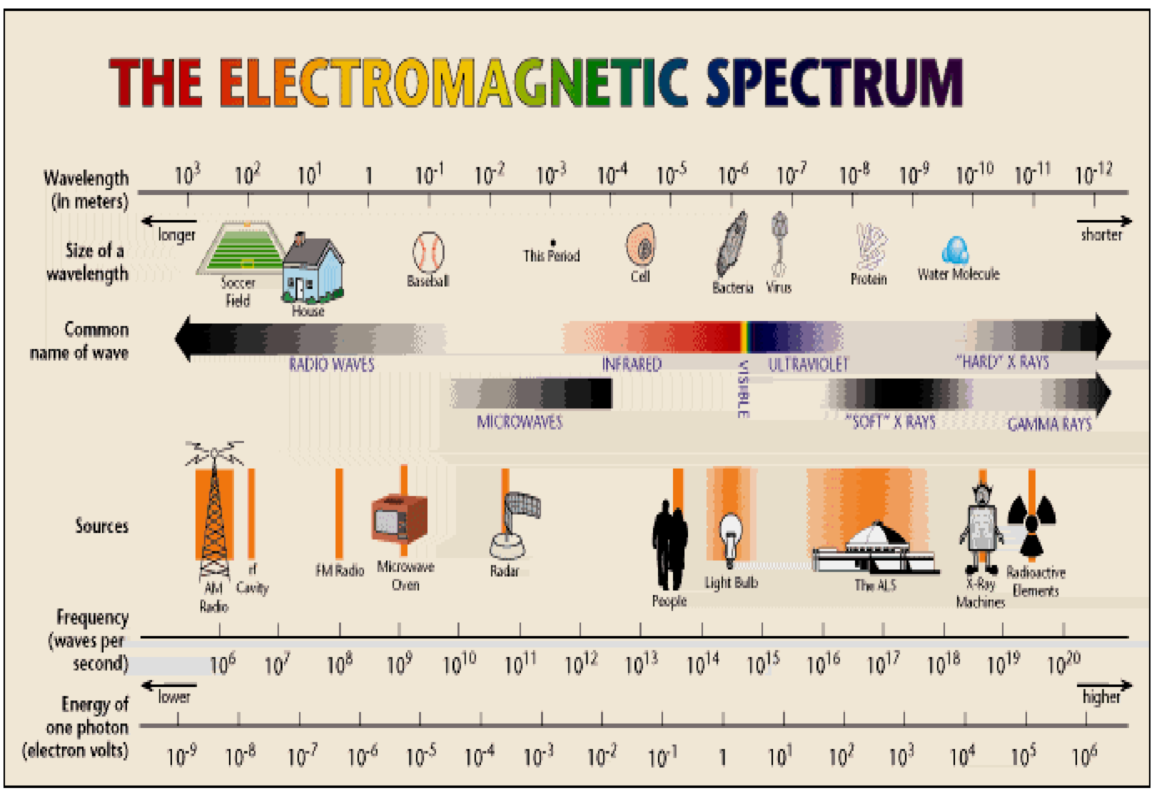
UNDERSTANDING WIRELESS: MEDIUM AND LONG-RANGE TECHNOLOGIES

By Joseph Kershenbaum

Back when Guglielmo Marconi began experimenting with “Hertzian waves” in 1894, wireless meant “wireless telegraphy” and Marconi called his system the “cable telegraph.” Hertzian waves later became known as radio waves and the cable telegraph became better known, at least in North America, as the radio.

Even the meaning of wireless itself has changed. Originally, wireless described telecommunications in which radio waves (rather than some form of wire conductor) carried a signal over all or part of a communications path. The definition of wireless today has broadened to incorporate other parts of the electromagnetic spectrum in which information is transmitted without wires. These include not only radio frequency (RF) transmission, but also communications via infrared, laser, visible light and acoustic energy.



Note: Frequencies below 100 KHz (10^5), such as Low Frequencies (LF), Very Low Frequencies (VLF), Extremely Low Frequencies (ELF) and voice frequencies (VF), are not shown.

Wireless communications has blossomed. In a mere 20 years, wireless services have accumulated more than one billion users and combined service revenues of nearly U.S. $400 billion a year. As wireless use has developed, it has engendered a great multitude of technical terms, jargon, trade names and legal definitions. This terminology is seldom readily understandable and, at best, is often confusing. Nonetheless, wireless technologies are expected to continue to grow dramatically in the next decade and play an increasingly greater role in our lives.

In this article, I will explain in the vernacular some of the wireless telecommunications terminology that is frequently used today. First, I will describe some of the categories by which wireless systems have been classified. I will then focus on medium to long-range wireless technologies. To this end, I will provide an overview of broadband wireless technologies. After that, I will detail the standard technologies underlying wireless cellular networks. Finally, I will describe the stages in the growth and development of wireless telecommunications networks and services.

Wireless Categories

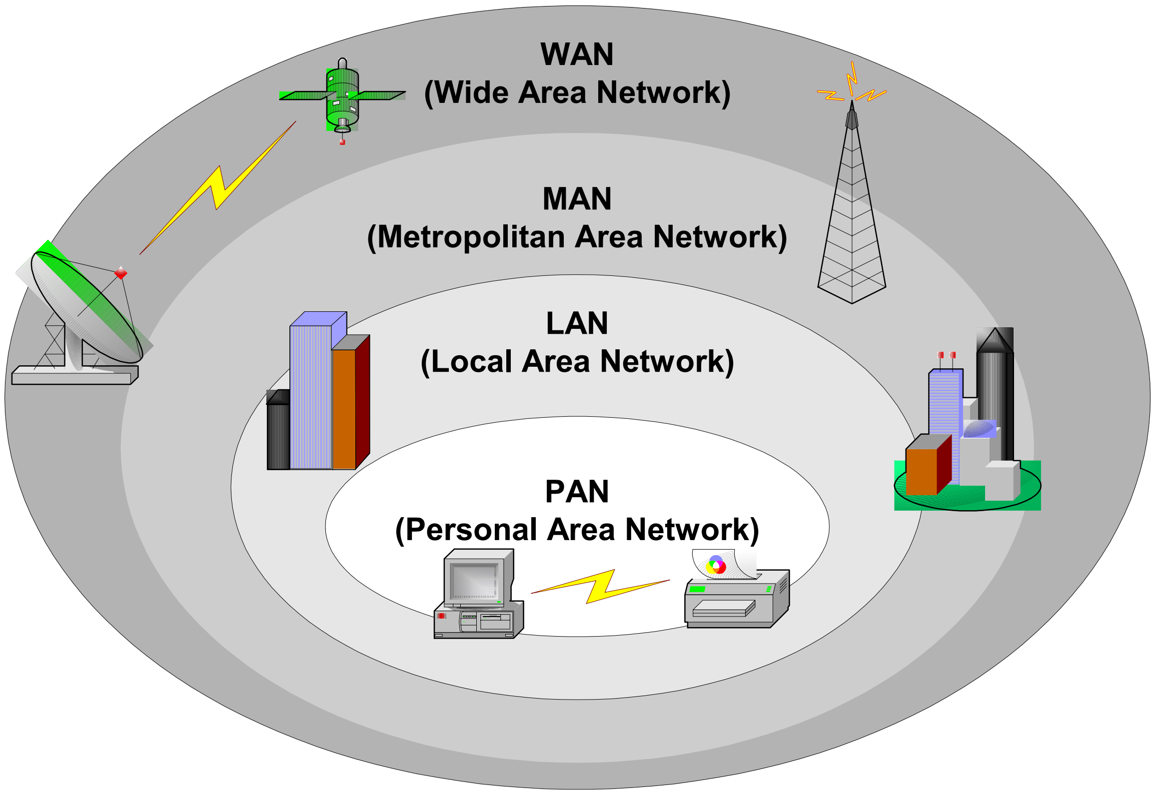
Wireless systems can be categorized in various ways, including, for example, classifications based on network architecture or mobility factors. These differing taxonomies—the way systems are organized—are one reason wireless can be so confusing. One wireless taxonomy bases its nomenclature on the area of spectrum utilized. Examples of this type of organization include:

- *IR wireless*: Communication with devices that utilize infrared (IR) radiation. Devices that use IR include home-entertainment remote-control boxes, wireless local area networks, links between notebook computers and desktop computers, cordless modems, intrusion detectors, motion detectors and fire sensors.

- *Acoustic wireless*: Communication by operating devices that employ acoustic waves. These include military (e.g., surveillance, underwater reconnaissance), government (e.g., earthquake and tsunami warning systems) and commercial applications (e.g., pipeline monitoring, ship traffic control).

An alternative categorization classifies wireless technologies by range. In this arrangement, the apportioning factor is the geographical region covered by the network.

WIRELESS COMMUNICATION NETWORKS



A Wide Area Network (WAN) covers a broad geographical area, such as a state or country. A Metropolitan Area Network (MAN) interconnects users in a city or similar-sized region. A MAN that connects several Local Area Networks (LAN) sometimes is referred to as a campus network. A LAN connects users in a small geographical area, such as an office building or complex. A PAN is a small wireless LAN, often connecting a single user's devices.

Yet another common method divides wireless systems into categories according to the type of device involved in the communication. These categories, which sometimes overlap, include:

- *Fixed wireless*: Communication using devices at fixed locations such as homes or offices. Standard utility mains typically power fixed wireless systems. Frequencies allotted for fixed wireless systems range from 900 megahertz (MHz) to 40 gigahertz (GHz).

  Many types of fixed wireless systems exist and have been developed based upon the frequency of the spectrum utilized. These systems include private licensed microwave links; private unlicensed links; 38 GHz carrier service; Local Multipoint Communications Systems (LMCS); Multichannel (or

Microwave) Multipoint Distribution Service (or System) (MMDS); optical wireless (laser); and Unlicensed National Information Infrastructure band (UNII). Even satellite service and high altitude aircraft systems proposed to offer round-the-clock wireless service are sometimes considered fixed wireless systems because their ground stations are at fixed locations.

The technical limitations of fixed wireless systems, dealt with below in greater detail, limit them to metropolitan area geographies. Therefore, they are considered MAN technologies.

- *Mobile wireless*: Communication via the operation of devices aboard motorized vehicles via battery power, such as personal communication services (PCS) units and automotive cell phones.

- *Portable wireless*: Communication by means of autonomous, battery-powered devices outside the home, office or vehicle, such as PCS units and handheld cell phones.

  Mobile and portable wireless systems are both WAN technologies.

Broadband Wireless

Like wireless, broadband also can be defined a number of ways. In its simplest description, broadband is a method of delivering voice, data and video using a wide range of frequencies at high speed over a given period of time. Broadband wireless is the wireless transmission of such information. Although spectrum licenses can be expensive, often, setting up a wireless transmission system is more economical, more convenient and faster to deploy than laying cable to the user.

When defined by the RF section of the electromagnetic spectrum that is employed, broadband wireless includes LMCS, MMDS and PCS. Broadband wireless also includes the transmission of information employing optical wireless technologies.

- *LMCS*: LMCS is a broadband microwave fixed wireless system that offers one-way and two-way communications. It was designed to provide voice, data and video (wireless cable television) service.

  LMCS is a point-to-multipoint service, which means that in an LMCS system, a local antenna transmits to receivers at homes and businesses. It provides connections of up to five miles, depending on the terrain and weather conditions. LMCS requires a clear line-of-sight between the transmitter and the receiver. This means that if a hill, trees, walls or similar obstructions are in the way, its signal can distort or fade. Rain also can scatter and distort the signal.

  Some LMCS providers offer two-way wireless transmission. This is called downstream and upstream or "symmetrical" service. Other providers offer only downstream or "asymmetrical" service and a wire connection is required for upstream service (Standard telephone lines supply the wire connection.). LMCS offers a bandwidth of up to 1.5 gigabytes per second (Gbps) downstream to users, although a more common transmission rate is 38 megabytes per second (Mbps) downstream. It offers 200 Mbps upstream from the user.

LMCS operates in the 27.5-31.3 GHz frequency band in North America and from 24-40 GHz overseas. In the United States, it is known as Local Multipoint Distribution Service (or System) (LMDS).

- *MMDS*: MMDS is a broadband microwave fixed wireless system quite similar to LMCS. The primary differences are that MMDS can operate over greater distances, but has less bandwidth than LMCS offers.

  Initially, MMDS began as a one-way service to broadcast wireless cable television. However, it could not compete with wireline and satellite cable offerings because quality was problematic and satellite television, in particular, offered a greater number of channels. While MMDS still provides up to 33 analog and more than 100 digital television channels in some locations, it now is available as a two-way transmission service, supplying voice and data communication applications, such as Internet service. In some cases, the upstream path employs a wire connection.

  In an MMDS system, an antenna located at or near the highest tower, tall building or mountain in a geographical area transmits to small microwave dishes. It has a range of up to 35 miles, depending on the terrain. Like LMCS, MMDS requires a clear line-of-sight between the transmitter and the receiver. When used for two-way service, MMDS, which operates on licensed and unlicensed channels, can transfer information at rates up to 30 Mbps over unlicensed channels or 1 Gbps over licensed channels. Two-way service reduces the effective range of MMDS to about 6 miles (10 km).

  MMDS operates in the 2.1-2.7 GHz frequency band in the United States and Canada and at 3.5 GHz in international markets.

- *PCS*: PCS is a two-way digital wireless voice and data service similar to cellular telephone (cell) service. In both PCS and cell systems, antennas blanket an area of coverage. As a user moves around, the nearest antenna acquires the user's signal and transmits it to a base station connected to the wired telephone network. PCS and cell systems use separate networks of antennas.

  PCS differs from cell service in several ways. PCS is digital while cell systems may be both analog and digital. PCS was meant to offer greater geographic coverage and thus, extended personal mobility than cell service, which was designed for use in cars with transmitters located around roads. PCS has fewer blind spots (areas in which access is not available) than cell service. PCS has smaller cells and thus, requires more antennas than cell systems. Further, PCS transmitters are generally closer together.

In North America, PCS operates in the 1850-1990 MHz frequency band while cellular systems operate at frequencies between 824-894 MHz.

- *Optical Wireless*: Optical wireless is a broadband fixed wireless system that offers two-way voice, data and video communication. In an optical wireless system, laser beams transmit information through the air. It also is referred to as atmospheric laser transmission, “free space optics” (FSO) or “free space photonics” (FSP).

  In an optical wireless system, two or more laser transceivers with a clear line of sight between them are aligned. A transceiver both transmits and receives signals, so there is full duplex (bi-directional) capability. Typically, optical wireless systems are used to link buildings and campuses together at distances of up to six kilometers.

  Four different optical wireless configurations exist. The first type is a dedicated point-to-point link between two terminals, such as two buildings. In the second, a point-to-multipoint architecture, a hub is placed on a tall building. The hub transmits to and receives signals from either the roofs or windows of surrounding buildings. The third kind of configuration is a series of transceivers connecting building roofs in a ring. The fourth method consists of short, redundant links connecting building roofs in a mesh configuration.

  Optical wireless systems are less expensive than RF-based systems because there is no cost for acquiring spectrum licenses. However, atmospheric conditions may impact performance. While rain, snow, dust and smog can block light transmission and thus, disrupt service, fog presents the greatest problem. Dense fog disrupts and dissipates laser signals because its small, dense moisture particles act like billions of tiny prisms. While technological advances have helped to minimize this concern, weather issues can limit the distance between transceivers. Another problem is that laser beams may misalign when buildings move because of solar and wind loading or small earthquakes, although systems with auto-alignment capabilities resolve this issue. Additionally, very small pockets of turbulent air may disrupt transmission, but the use of multiple transmitters and receivers solves this problem. Finally, flying objects, such as birds, can disrupt communications and require retransmission of information, although this is not a concern for redundant mesh configurations.

  Optical wireless can transfer information at up to 1 Gbps. It operates in the infrared portion of the electromagnetic spectrum, typically at wavelengths ranging from 750 to 1,550 nanometers (nm).

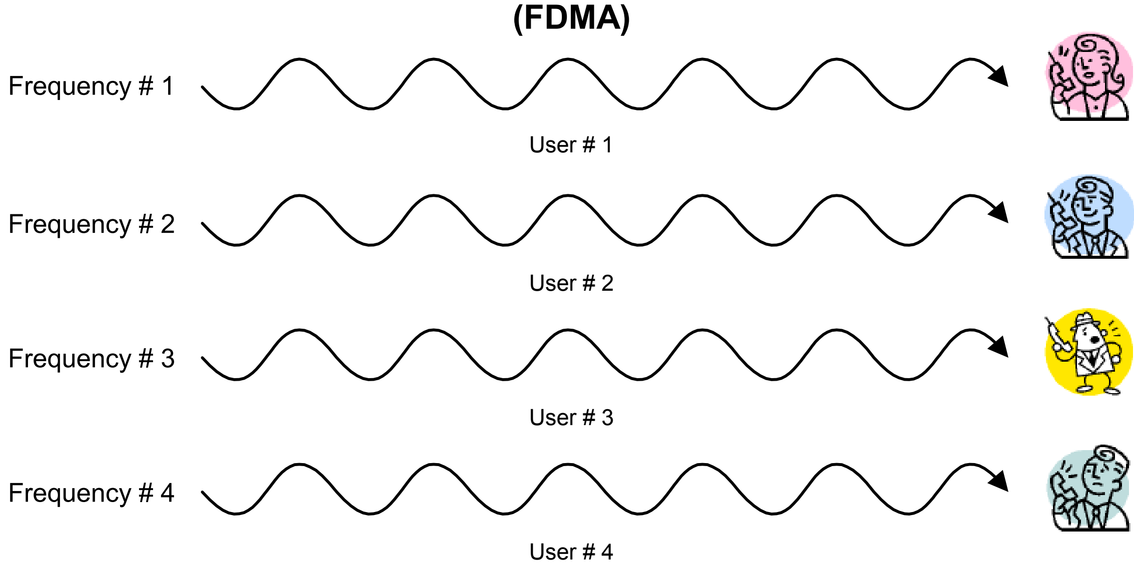
Wireless Cellular Network Technologies

Several standard technologies provide the means by which PCS and cellular telephone networks may operate. While there are quite a number of variations, there are three basic themes: FDMA, TDMA and CDMA. Each differs in the technique—time, space or frequency—used for sharing the RF spectrum. In other words, these three major wireless standards offer different ways of multiplexing.

Multiplexing means combining and transmitting two or more signals or streams of information simultaneously as a single complex signal. Demultiplexing refers to recovering the individual signals at the receiving end. Because they multiplex in different ways, the three standards are incompatible.

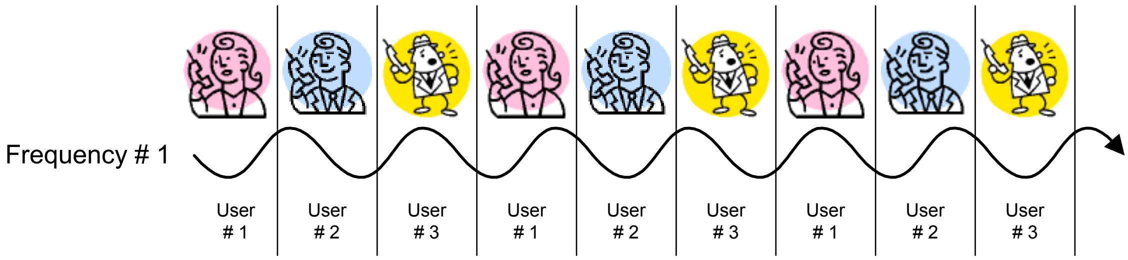
- *Frequency Division Multiple Access (FDMA)*: FDMA works by dividing the RF spectrum into a range of frequencies. Each user is assigned to a different 30 KHz wide channel. It is used by analog mobile phone systems and is still in use today, primarily in rural areas. It is not efficient for digital communications because it requires a lot of bandwidth. In an FDMA system, multiple frequency channels are required for each call (one for the uplink and one for the downlink).

FREQUENCY DIVISION MULTIPLE ACCESS (FDMA)



- *Time Division Multiple Access (TDMA):* Like FDMA communication systems, TDMA systems also divide the RF spectrum into 30 KHz channels. However, in a TDMA system, the 30 KHz channel is further divided into tiny time slots that are 6.7 milliseconds (ms) long. Each user takes turns communicating in rotation over the channel by having access to one time slot at regular intervals. Thus, TDMA tripled the capacity of the original FDMA-based analog systems. In a TDMA system, multiple calls may be made on a single frequency.

TIME DIVISION MULTIPLE ACCESS (TDMA)



TDMA is used in communications networks such as the Global System for Mobile Communications (GSM), Integrated Digital Enhanced Network (iDEN, a technology that combines a mobile phone with a two-way dispatch business radio) and Personal Digital Cellular (PDC), a system used in Japan.

- *Global System for Mobile Communications (GSM):* Originally called Groupe Spécial Mobile, GSM is the world's most widely used mobile communications system. It presently provides seamless, same number communication in more than 170 countries.

  GSM operates on a 25 MHz-wide frequency band by combining FDMA and TDMA access schemes. First, using FDMA, it divides the 25 MHz band into 124 200 KHz channels. Then, using TDMA, it divides each 200 KHz channel into eight separate timeslots, each .577 ms long. Users communicate in turn by having access to one timeslot at regular intervals. This is known as Narrowband TDMA technology.

- *Code Division Multiple Access (CDMA):* CDMA is a digital technology that divides the RF spectrum into 1.25 MHz wide channels, much larger than those in FDMA or TDMA systems. With CDMA, a unique code, known as a pseudo-random code sequence, is assigned to each user's signal in order to differentiate users. The signal is then transmitted simultaneously with all other users' signals on the same channel. At the receiving end, the user's unique code is deciphered and used to extract and reassemble the user's specific information from all other information being broadcast. CDMA is known as "spread spectrum" technology because the signal is spread across a bandwidth much wider than the original signal.

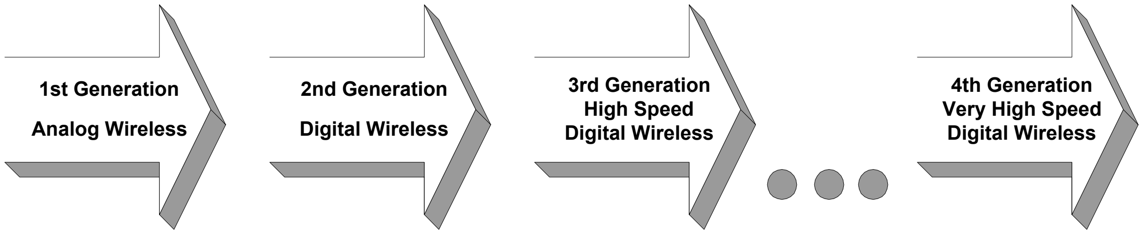
The difference between TDMA and CDMA has been compared to conversations involving different languages. In a TDMA system, each person takes turns speaking in his own language. However, in a CDMA system, the listener listens for the one person speaking his language in a place where everyone speaks simultaneously in a different language.

CDMA has many advantages over FDMA and TDMA. First, there are about 4.4 trillion possible frequency-sequencing codes, allowing for much greater use of frequency bands and thus, greater capacity. CDMA systems offer 8-20 times the capacity of FDMA systems and three times the capacity of TDMA systems. The trillions of combinations also provide enhanced privacy and security. Second, it is a low power system that increases battery life in mobile units. Third, its unique coding allows for improved transmission quality, with no crosstalk or interference. Fourth, its spread spectrum technology allows networks to be built with fewer cell sites, improving coverage while lowering system costs and planning. Finally, because it is a packet-switched technology (discussed below under GPRS), it offers bandwidth on demand.

CODE DIVISION MULTIPLE ACCESS (CDMA)

Wireless Generations

1G, 2G, 3G, 4G and intermediate steps, such as 2.5G, describe stages in the growth and development of wireless networks and services. "G" means generation.



- *1G*: The first generation of wireless service provided voice communication via analog mobile phones, but no data transmission. Analog mobile wireless service began in the late 1970s and early 1980s. They operated using FDMA.

  Several different systems existed. In North and South America and 35 other countries, the system deployed was the Advanced Mobile Phone Service (AMPS). It began operating in the U.S. in the early 1980s in the 800 MHz band. Another system, Nordic Mobile Telephone, was deployed in more than 40 European countries. It operated in the 450 and 900 MHZ frequency bands. Another European system, the Total Access Communication System (TACS), operated at frequencies in the 800-900 MHz range.

  Analog systems offered limited capacity; as traffic increased, bandwidth constraints reduced service. Further, handoff between cells was unreliable.

- *2G*: In the early 1990s, service providers introduced second generation wireless cellular systems. These systems were digital; they are referred to as digital cellular and PCS systems. They primarily have been used for voice communication, but offer enhanced features, such as caller ID. In North America, they operate using GSM, TDMA, CDMA and iDEN to communicate.

  2G systems, like 1G ones, are based on circuit-switched technology. In such a system, each call requires its own cell channel, which makes data transmission very slow. Thus, 2G systems are oriented to simple, low speed data services, such as Short Message Service (SMS), a point-to-point text message service offered on GSM systems that allows a user to send messages of up to 160 characters to another user simply by entering the recipient's phone number. SMS is similar to paging, except that a cell phone can receive a message even if a voice or data transmission is in progress.

  Digital systems offer a number of advantages over analog ones. They require lower power and provide better voice quality and greater security and transmission capacity (from 9.6-14.4 Kbps). In North America, 2G cellular systems operate at frequencies between 824-894 MHz and PCS operates in the 1850-1990 MHz frequency band.

- *2.5G*: The present state of wireless infrastructure is commonly referred to as 2.5G or 2G+, a phase between second and third generation technology. 2.5G appeared as a cost-effective migration to 3G because the cost of upgrading directly from 2G to 3G networks is quite expensive. Essentially, it extended 2G systems to increase data transmission rates, so that additional features such as enhanced email and Internet access may be offered.

2.5G systems introduce technologies such as:

- General Packet Radio Services (GPRS) and High Speed Circuit-Switch Data (HSCSD) for GSM networks, which offers increased data transmission capabilities;

- Enhanced Data GSM Environment (EDGE), a faster version of GSM service that increases data rates for GSM and TDMA networks; and

- Interim Standard 95B (IS-95B) and High Data Rate (HDR), which improves data transmission capacity for CDMA networks.

GPRS and EDGE are packet-switched technologies. In such a system, information is broken up into discrete packets or data and transmitted over the network to its destination. Network resources are used only when packets are transmitted. This is more efficient than circuit-switching, used in traditional phone systems and 2G networks, in which a single circuit must be dedicated to the users for the duration of the connection. Packet-switched phones seem to be always connected to the network compared with circuit-switched connections, in which a user must dial into a network and thus, a setup time of up to 30 second to connect to the network occurs.

- 3*G*: The third generation of mobile wireless communications will be packet-switched. It will provide an enormous leap in the speed and capacity of wireless networks, offering high-quality voice, data and full-motion video transmission capabilities. 3G's design contemplates that a user will be able to go anywhere in Europe, Japan and North America and be connected seamlessly to any other user through fixed, mobile or portable wireless systems on or over the earth's surface. Cell phone, email, fax, paging, videoconferencing and the World Wide Web will be accessible over 3G systems.

  3G systems will be based on CDMA technology. Although the path of migration is still unclear, it is anticipated that CDMA-based systems, known as CDMA1 or CDMA One, will advance to CDMA2000 systems and TDMA-based systems (including GSM) will evolve to Wideband CDMA (W-CDMA).

  3G networks are planned to transmit information at 144 kilobits per second for mobile traffic (traveling greater than 75 miles per hour in outdoor environments), 384 kbps for "pedestrian" users (traveling less than 75 miles per hour in outdoor environments) and 2 megabits per second in fixed locations (stationary indoor locations or outdoor locations of low mobility (traveling less than about 6 miles per hour). 3G systems will operate in the 2Ghz frequency band.

- *4G*: Fourth generation wireless is the stage of communications that will follow the still-developing 3G. The boundaries between 3G and 4G systems are not clear, although as with earlier generation, 4G services will offer vastly increased data transmission rates, up to 20-40 Mbps initially and advancing to 100 Mbps thereafter. Anticipated 4G features include worldwide roaming capability, which means that the system will connect the entire globe and be accessible from any location on or above the earth, and wireless video conferencing in 3D, an enhancement not even available in wireline today.

While the recent global economic slowdown has delayed the introduction of 3G systems, Guglielmo Marconi might well be amazed at the extent to which wireless telecommunications technologies have permeated our lives. Similarly, it is hard for us to conceive of which standards will dominate and what applications will appeal to us in years hence. What we can expect is that wireless technologies will continue to play a significant role in communications infrastructures and thus, they will have a substantial effect on expanding our ability to convey information.

 Joseph Kershenbaum, B.A., M.B.A., J.D. (joseph@kershenbaum.com), is a technology executive and attorney who has advised manufacturers and service providers in the telecommunications industry. The author wishes to thank Edward Kershenbaum, B.S., M.B.A., formerly with SBC Communications Inc. and the senior technology officer of a number of leading companies, for his assistance with this article.