Mobile computing requires hardware, software, and networks. The major infrastructure components of mobile computing are described in this section.

MOBILE COMPUTING HARDWARE

To conduct mobile commerce (e-commerce conducted over mobile computing devices), one needs devices for data entry and access to the Internet, applications, and other equipment. Several hardware devices are used in mobile computing. The major ones are:

- **Cellular (mobile) phones.** All major cell phone manufacturers are making (or plan to make) Internet-enabled phones, also known as smartphones. These cell phones are improving with time, adding more features, larger screens, keyboards, and more. Over 35 percent of the new cell phones have color screens (Pilato, 2002), for example. An example of an Internet-enabled cell phone is the Nokia 3510i, which includes Internet access, multimedia messaging (MMS), support for small Java applications (like games), a calculator, schedule, address book, and more. Note that even phones without screen displays (regular or cellular phones) can be used to retrieve voice information from the Web (see tellme.com and the discussion of voice portals in Section 6.2).

- **Attachable keyboard.** Transactions can be executed with the regular handset entry keys, but it is fairly time-consuming to do so. An alternative is to use a larger cell phone such as the Nokia 9290 that contains a small-scale keyboard. Yet another solution is to plug an attachable keyboard into the cell phone. (Attachable keyboards are also available for other wireless devices, such as PDAs.)

- **PDAs.** Personal digital assistants (PDAs) with Internet access are now available from several vendors, and their capabilities are increasing. Using special software, users can connect these PDAs to the Internet via a wireless modem. PDAs for corporate users include additional capabilities, such as e-mail synchronization and exchange of data and backup files with corporate servers. (Examples of PDAs for corporate users are Jornada from HP, Sony NX70V, and MobilePro from NEC.)

- **Interactive pagers.** Some two-way pagers can be used to conduct limited mobile computing and m-commerce activities on the Internet (mainly sending and receiving text messages, such as stock market orders).

- **Screenphones.** A telephone equipped with a color screen, possibly a keyboard, e-mail, and Internet access is referred to as a screenphone. Initially, these were wirelined; that is, they were regular phones connected by wires to a network. As of 2000, wireless screenphones became available.

- **E-mail handhelds.** To enhance wireless e-mail capabilities, one can use devices such as the BlackBerry handheld (blackberry.net). This device, which includes a keypad, is an integrated package, so there is no need to dial into an Internet provider for access. A variety of services for data communication enable users to receive and send messages from anywhere. For example, the law firm of Paul, Hastings, Janofsky, & Walker (with offices in major U.S. cities) has deployed BlackBerry handhelds to its 900 lawyers, who can now receive their e-mail in real time and can enter billing information while on the road. Furthermore, they can be alerted whenever they have a voice mail or fax waiting. A third of the company’s lawyers have returned their laptops, and the company has saved $260,000 each year as a result of these trade-ins. New applications are coming with each new version of the handhelds (for details see Cohen, 2002). A product demo is available at blackberry.net.

- **Other devices.** Many other wireless support devices are on the market. For example, the Seiko SmartPad (siibusinessproducts.com) allows you to handwrite from a notepad instantly to a cell phone or PDA screen, overcoming the small screen size...
of these devices. Some new cell phones have built-in cameras; you can take a picture and e-mail it immediately from your mobile location. Finally there is a wireless mouse, which works up to 15 feet, so it can be used for presentations. For an overview of devices see Kridel (2003).

There is a significant trend toward the convergence of PDAs and cell phones. On the one hand, the PDA manufacturers are providing PDAs with cellular or wireless capabilities. On the other hand, the cellular phone manufacturers and systems providers are offering phones with PDA capabilities.

In addition to the hardware described above, m-commerce also requires the following infrastructure hardware, most of which the user does not see or know about, but which is essential for wireless connectivity:

- A suitably configured wireline or wireless WAN modem, wireless LAN adapter, or wireless MAN (metro-area network) adapter.
- A Web server with wireless support, a WAP gateway, a communications server, and/or a mobile communications server switch (MCSS). Such a Web server provides communications functionality that enables the handheld device to communicate with the Internet or intranet infrastructure (see mobileinfo.com).
- An application or database server with application logic and a business application database.
- A large enterprise application server.
- A GPS (global positioning system) locator that is used to determine the location of the person carrying the mobile computing device. This is the basis for location-based applications.

## MOBILE COMPUTING SOFTWARE

Developing software for wireless devices is challenging because, as of 2004, there is no widely accepted standard for wireless applications. Therefore, software applications need to be customized for each type of device with which the application may communicate. The major software products required for mobile computing are presented in Table W6.1.1.

### Table W6.1.1 Software for Mobile Computing

<table>
<thead>
<tr>
<th>Software</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbrowser</td>
<td>A browser with limited bandwidth and memory requirements. Provides wireless access to the Internet.</td>
</tr>
<tr>
<td>Operating system (OS) for mobile-client</td>
<td>An OS for mobile devices. Example: Palm OS, Windows 2001NT, Win CE. Specialized OSs: BlackBerry and Web browser.</td>
</tr>
<tr>
<td>User interface</td>
<td>Application logic for handheld devices. It is often controlled by the microbrowser.</td>
</tr>
<tr>
<td>Legacy application software</td>
<td>Residing on the mainframe, it is a major source of data to wireless systems.</td>
</tr>
<tr>
<td>Application middleware</td>
<td>Provides connections on the mainframe.</td>
</tr>
<tr>
<td>Wireless middleware</td>
<td>Links wireless networks to application servers.</td>
</tr>
<tr>
<td>Wireless Application Protocol (WAP)</td>
<td>A set of communication protocols that enables wireless devices to “talk” to a server on a mobile network, so users can access the Internet. Specially designed for small screen. A competing standard is the J2ME platform, which offers better security, and graphics (see wapforum.org).</td>
</tr>
<tr>
<td>Wireless Markup Language (WML)</td>
<td>An XML-based scripting language for creating content for wireless systems.</td>
</tr>
<tr>
<td>Voice XML</td>
<td>An extension of XML designed to accommodate voice.</td>
</tr>
</tbody>
</table>
WIRELESS WIDE AREA NETWORKS (WWANS)

At the core of most mobile computing applications are mobile networks. These are of two general types: the wide area and the local area. The wide area networks for mobile computing are known as wireless wide area networks (WWANs). The breadth of coverage of WWANs directly affects the availability of services (see Intel, 2002). Breadth of coverage depends on the transmission media and the generation of wireless.

The global communications and cellular phone companies operate most of the wireless wide area networks. A very simple mobile system is shown in Figure W6.1.1. At the edge of the system are the mobile handsets. A mobile handset consists of two parts—terminal equipment that hosts the applications (e.g., a PDA) and a mobile terminal (e.g., a cell phone) that connects to the mobile network.

TRANSMISSION MEDIA

Several transmission media can be used for wireless transmission. These media differ in both capabilities and cost. A comprehensive discussion is provided in Chapter 4 and Technology Guide 4. For details on transmission media, see Sadeh (2002) and Mennecke and Strader (2003).

Communication Generations of Wireless Wide Area Networks

The success of mobile computing depends on the capabilities of the WWAN communication systems. Four (and a half) generations of communications technology are distinguished:

- **1G.** The first generation of wireless technology. It was an analog-based technology, in effect from 1979 to 1992.
- **2G.** The second generation of digital wireless technology. In existence today, 2G is based on digital radio technology and mainly accommodates text.
- **2.5G.** An interim technology based on GPRS (General Packet Radio Services) and EDGE (Enhanced Data Rates for Global Evaluation) that can accommodate limited graphics.
- **3G.** The third generation of digital wireless technology, which supports rich media such as video clips. It started in 2001 in Japan, and reached Europe in 2002 and the United States in 2003. As of 2003, the number of 3G cell phones in operation was around 150 million (a small percentage of the total number cell phones in use today) (Dunne, 2001).
- **3G** The third generation of digital wireless technology; supports rich media such as video clips.
4G. The expected next generation of wireless technology.

Some mobile handsets, especially in Europe, contain a **subscriber identification module (SIM) card**. This is an extractable storage card that is used not only for identification but also for providing customer location information, transaction processing, secure communications, and the like. A SIM card makes it possible for a handset to work with multiple phone numbers.

The mobile handset communicates with a **base-transceiver station**. There are thousands of these throughout the world. A base-transceiver station is connected to a **base-station controller** that handles the handoff from one transceiver to the next as the customer or user travels from one place to another. The various base-station controllers are connected to **mobile switching centers** that connect the mobile network with the public wired phone network.

### Communication Protocols in WWANs

One of the major problems facing the mobile communication system providers is how to service extremely large numbers of users given limited communication bandwidth. This can be done through multiplexing protocols (see Technology Guide 4). In today’s mobile world (2004), there are three main protocols:

1. **Frequency Division Multiple Access (FDMA)**. Used by 1G systems, this protocol gives each user a different frequency to communicate on.
2. **Time Division Multiple Access (TDMA)**. Used with some of the more popular 2G systems, this protocol assigns different users different time slots on a given communications channel.
3. **Code Division Multiple Access (CDMA)**. Used with most 2.5G and 3G systems, this protocol separates different users by assigning different codes to the segments of each user’s communications.

In today’s mobile world, most of the networks rely on either TDMA or CDMA.