

## Topic 2 Notes

### 2.1 Introduction

**Mobile computing** is human-computer interaction by which a computer is expected to be transported during normal usage. Mobile computing involves mobile communication, mobile hardware, and mobile software. Communication issues include ad-hoc and infrastructure networks as well as communication properties, protocols, data formats and concrete technologies. Hardware includes mobile devices or device components. Mobile software deals with the characteristics and requirements of mobile applications.

**Wireless communication** is the transfer of information over a distance without the use of electrical conductors or wires. The term "Wireless" came into public use to refer to a radio receiver or transceiver (a dual-purpose receiver and transmitter device), today the term is used to describe modern wireless connections such as in cellular networks and wireless broadband Internet. It is also used in a general sense to refer to any type of operation that is implemented without the use of wires, such as "wireless remote control", "wireless energy transfer", etc. regardless of the specific technology (e.g., radio, infrared, ultrasonic, etc.) that is used to accomplish the operation. Wireless communications encompass various types of fixed, mobile, and portable two-way radios, cellular telephones, personal digital assistants (PDAs Wireless computer mice, keyboards and headsets, satellite television and cordless telephones.

The term "wireless" has become a generic and all-encompassing word used to describe communications in which electromagnetic waves or RF carry a signal over part or the entire communication path. Common examples of wireless equipment in use today include:

- Global Positioning System (GPS)
- Cordless Computer Peripherals
- Cordless Telephone Sets
- Satellite Television
- Wireless Gaming

The term "wireless" should not be confused with the term "cordless", which is generally used to refer to powered electrical or electronic devices that are able to operate from a portable power source (e.g., a battery pack) without any cable or cord to limit the mobility of the cordless device through a connection to the main power supply.

Wireless communication can be via;

- Radio frequency
- Microwave (i.e. long-range and line-of-sight via antennas or short range communications)
- GSM
- GPRS
- 3G
- GPS
- ZigBee

#### 2.1.1 Definitions

**Mobile computing** is "taking a computer and all necessary files and software out into the field."

**"Mobile computing:** being able to use a computing device even when being mobile and therefore changing location. Portability is one aspect of mobile computing."

**"Mobile computing** is the ability to use computing capability without a pre-defined location and/or connection to a network to publish and/or subscribe to information ."

**Mobile Computing** is a variety of wireless devices that has the mobility to allow people to connect to the internet, providing wireless transmission to access data and information from where ever location they may be.

Mobile Computing is a modified and new way of interacting with the computer device and to facilitate the other computing capabilities being present at different mobile locations.

**Wireless telecommunication** is the transfer of information between two or more points that are not physically connected. Distances can be short, such as a few meters for television remote control, or as far as thousands or even millions of kilometers for deep-space radio communications. It encompasses various types of fixed, mobile, and portable two-way radios, cellular telephones, personal digital assistants (PDAs), and wireless networking. Other examples of wireless technology include GPS units, Garage door openers or garage doors, wireless computer mice, keyboards and Headset (audio), headphones, radio receivers, satellite television, broadcast television and cordless telephones.

## **2.2 Evolution of mobile communication**

At the initial phase, mobile communication was restricted to certain official users and the cellular concept was never even dreamt of being made commercially available.

Moreover, even the growth in the cellular networks was very slow. However, with the development of newer and better technologies starting from the 1970s and with the mobile users now connected to the PSTN, there has been a remarkable growth in the cellular radio. However, the spread of mobile communication was very fast in the 1990s when the government throughout the world provided radio spectrum licenses for Personal Communication Service (PCS) in 1.8 - 2 GHz frequency band.

### **2.2.1 1G: First Generation Networks**

The first mobile phone system in the market was AMPS. It was the first U.S. cellular telephone system, deployed in Chicago in 1983. The main technology of this first generation mobile system was FDMA/FDD and analog FM.

### **2.2.2 2G: Second Generation Networks**

Digital modulation formats were introduced in this generation with the main technology as TDMA/FDD and CDMA/FDD. The 2G systems introduced three popular TDMA standards and one popular CDMA standard in the market. These are as follows:

#### **2.2.2.1 TDMA/FDD Standards**

(a) Global System for Mobile (GSM): The GSM standard, introduced by Groupe Special Mobile, was aimed at designing a uniform pan-European mobile system. It was the first fully digital system utilizing the 900 MHz frequency band. The initial GSM had 200 KHz radio channels, 8 full-rate or 16 half-rate TDMA channels per carrier, encryption of speech, low speed data services and support for SMS for which it gained quick popularity.

(b) Interim Standard 136 (IS-136): It was popularly known as North American Digital Cellular (NADC) system. In this system, there were 3 full-rate TDMA users over each 30 KHz channel. The need of this system was mainly to increase the capacity over the earlier analog (AMPS) system.

(c) Pacific Digital Cellular (PDC): This standard was developed as the counterpart of NADC in Japan. The main advantage of this standard was its low transmission bit rate which led to its better spectrum utilization.

#### **2.2.2.2 CDMA/FDD Standard**

Interim Standard 95 (IS-95): The IS-95 standard, also popularly known as CDMA One, uses 64 orthogonally coded users and codewords are transmitted simultaneously on each of 1.25 MHz channels. Certain services that have been standardized as a part of IS-95 standard are: short messaging service, slotted paging, over-the-air activation (meaning the mobile can be activated by the service provider without any third party intervention), enhanced mobile station identities etc.

#### **2.2.2.3 2.5G Mobile Networks**

In an effort to retrofit the 2G standards for compatibility with increased throughput rates to support modern Internet application, the new data centric standards were developed to be overlaid on 2G standards and this is known as 2.5G standard. Here, the main upgradation techniques are:

- \_ supporting higher data rate transmission for web browsing
- \_ supporting e-mail traffic
- \_ enabling location-based mobile service

2.5G networks also brought into the market some popular application, a few of which are: Wireless Application Protocol (WAP), General Packet Radio Service (GPRS), High Speed Circuit Switched Data (HSCSD), Enhanced Data rates for GSM Evolution (EDGE) etc.

### **2.2.3 3G: Third Generation Networks**

3G is the third generation of mobile phone standards and technology, superseding 2.5G. It is based on the International Telecommunication Union (ITU) family of standards under the International Mobile Telecommunications-2000 (IMT-2000). ITU launched IMT-2000 program, which, together with the main industry and standardization bodies worldwide, targets to implement a global frequency band that would support a single, ubiquitous wireless communication standard for all countries, to provide the framework for the definition of the 3G mobile systems. Several radio access technologies have been accepted by ITU as part of the IMT-2000 framework.

3G networks enable network operators to offer users a wider range of more advanced services while achieving greater network capacity through improved spectral efficiency. Services include wide-area wireless voice telephony, video calls, and broadband wireless data, all in a mobile environment. Additional features also include HSPA data transmission capabilities able to deliver speeds up to 14.4Mbit/s on the down link and 5.8Mbit/s on the uplink.

3G networks are wide area cellular telephone networks which evolved to incorporate high-speed internet access and video telephony. IMT-2000 defines a set of technical requirements for the realization of such targets, which can be summarized as follows:

- i. high data rates: 144 kbps in all environments and 2 Mbps in low-mobility and indoor environments
- ii. symmetrical and asymmetrical data transmission
- iii. circuit-switched and packet-switched-based services
- iv. speech quality comparable to wire-line quality
- v. improved spectral efficiency
- vi. several simultaneous services to end users for multimedia services
- vii. seamless incorporation of second-generation cellular systems
- viii. global roaming
- ix. open architecture for the rapid introduction of new services and technology.

#### **2.2.3.1 3G Standards and Access Technologies**

As mentioned before, there are several deferent radio access technologies defined within ITU, based on either CDMA or TDMA technology. An organization called 3rd Generation Partnership Project (3GPP) has continued that work by defining a mobile system that fulfills the IMT-2000 standard. This system is called Universal Mobile Telecommunications System (UMTS). After trying to establish a single 3G

standard, ITU finally approved a family of five 3G standards, which are part of the 3G framework known as IMT-2000:

- i. W-CDMA
- ii. CDMA2000
- iii. TD-SCDMA

Europe, Japan, and Asia have agreed upon a 3G standard called the Universal Mobile Telecommunications System (UMTS), which is WCDMA operating at 2.1 GHz. UMTS and WCDMA are often used as synonyms. In the USA and other parts of America, WCDMA will have to use another part of the radio spectrum.

### **2.2.3.2 3G W-CDMA (UMTS)**

WCDMA is based on DS-CDMA (direct sequence code division multiple access) technology in which user-information bits are spread over a wide bandwidth (much larger than the information signal bandwidth) by multiplying the user data with the spreading code. The chip (symbol rate) rate of the spreading sequence is 3.84 Mcps, which, in the WCDMA system deployment is used together with the 5-MHz

carrier spacing. The processing gain term refers to the relationship between the signal bandwidth and the information bandwidth. Thus, the name wideband is derived to differentiate it from the 2G CDMA (IS-95), which has a chip rate of 1.2288 Mcps. In a CDMA system, all users are active at the same time on the same frequency and are separated from each other with the use of user specific spreading codes.

The wide carrier bandwidth of WCDMA allows supporting high user-data rates and also has certain performance benefits, such as increased multipath diversity.

The actual carrier spacing to be used by the operator may vary on a 200-kHz grid between approximately 4.4 and 5 MHz, depending on spectrum arrangement and the interference situation. In WCDMA each user is allocated frames of 10 ms duration, during which the user-data rate is kept constant. However, the data rate among the users can change from frame to frame. This fast radio capacity allocation (or the limits for variation in the uplink) is controlled and coordinated by the radio resource management (RRM) functions in the network to achieve optimum throughput for packet data services and to ensure sufficient quality of service (QoS) for circuit-switched users. WCDMA supports two basic modes of operation: FDD and TDD. In the FDD mode, separate 5-MHz carrier frequencies with duplex spacing are used for the uplink and downlink, respectively, whereas in TDD only one 5-MHz carrier is time shared between the uplink and the downlink. WCDMA uses coherent detection based on the pilot symbols and/or common pilot. WCDMA allows many performance- enhancement methods

to be used, such as transmit diversity or advanced CDMA receiver concepts. The support for handovers (HO) between GSM and WCDMA is part of the first standard version. This means that all multi-mode WCDMA/GSM terminals will support measurements from the one system while camped on the other one. This allows networks using both WCDMA and GSM to balance the load between the networks and base the HO on actual measurements from the terminals for different radio conditions in addition to other criteria available.

### **2.2.3.3 3G CDMA2000**

Code division multiple access 2000 is the natural evolution of IS-95 (CDMA One). It includes additional functionality that increases its spectral efficiency and data rate capability. (code division multiple access) is a mobile digital radio technology where channels are defined with codes (PN sequences). CDMA permits many simultaneous transmitters on the same frequency channel. Since more phones can be served by fewer cell sites, CDMA-based standards have a significant economic advantage over TDMA- or FDMA-based standards. This standard is being developed by Telecommunications Industry Association (TIA) of US and is standardized by 3GPP2.

The main CDMA2000 standards are: CDMA2000 1xRTT, CDMA2000 1xEV and CDMA2000 EV-DV. These are the approved radio interfaces for the ITU's IMT-2000 standard. In the following, a brief discussion about all these standards is given.

CDMA2000 1xRTT: RTT stands for Radio Transmission Technology and the designation "1x", meaning "1 times Radio Transmission Technology", indicates the same RF bandwidth as IS-95. The main features of CDMA2000 1X are as follows:

- \_ Supports an instantaneous data rate upto 307kbps for a user in packet mode and a typical throughput rates of 144kbps per user, depending on the number of user, the velocity of user and the propagating conditions.

- \_ Supports up to twice as many voice users as the 2G CDMA standard

- \_ Provides the subscriber unit with upto two times the standby time for longer lasting battery life.

CDMA2000 EV: This is an evolutionary advancement of CDMA with the following characteristics:

- \_ Provides CDMA carriers with the option of installing radio channels with data only (CDMA2000 EV-DO) and with data and voice (CDMA2000 EV-DV) .

- \_ The cdma2000 1xEV-DO supports greater than 2.4Mbps of instantaneous high-speed packet throughput per user on a CDMA channel, although the user data rates are much lower and highly dependent on other factors.

- \_ CDMA2000 EV-DV can offer data rates upto 144kbps with about twice as many voice channels as IS-95B. CDMA2000 3x is (also known as EV-DO Rev B) is a multi-carrier evolution.

- \_ It has higher rates per carrier (up to 4.9 Mbit/s on the downlink per carrier). Typical deployments are expected to include 3 carriers for a peak rate of 14.7 Mbit/s. Higher rates are possible by bundling multiple channels together. It enhances the user experience and enables new services such as high definition video streaming.

- \_ Uses statistical multiplexing across channels to further reduce latency, enhancing the experience for latency-sensitive services such as gaming, video telephony, remote console sessions and web browsing.

- \_ It provides increased talk-time and standby time.

- \_ The interference from the adjacent sectors is reduced by hybrid frequency reuse and improves the rates that can be offered, especially to users at the edge of the cell.

- \_ It has efficient support for services that have asymmetric download and upload requirements (i.e. different data rates required in each direction) such as file transfers, web browsing, and broadband multimedia content delivery.

### **2.2.3.4 3G TD-SCDMA**

Time Division-Synchronous Code Division Multiple Access, or TD-SCDMA, is a 3G mobile telecommunications standard, being pursued in the People's Republic of China by the Chinese

Academy of Telecommunications Technology (CATT). This proposal was adopted by ITU as one of the 3G options in late 1999. TD-SCDMA is based on spread spectrum technology. TD-SCDMA uses TDD, in contrast to the FDD scheme used by W-CDMA.

By dynamically adjusting the number of timeslots used for downlink and uplink, the system can more easily accommodate asymmetric traffic with different data rate requirements on downlink and uplink than FDD schemes. Since it does not require paired spectrum for downlink and uplink, spectrum allocation flexibility is also increased. Also, using the same carrier frequency for uplink and downlink means that the channel condition is the same on both directions, and the base station can deduce the downlink channel information from uplink channel estimates, which is helpful to the application of beamforming techniques.

TD-SCDMA also uses TDMA in addition to the CDMA used in WCDMA. This reduces the number of users in each timeslot, which reduces the implementation complexity of multiuser detection and beamforming schemes, but the non-continuous transmission also reduces coverage (because of the higher peak power needed), mobility (because of lower power control frequency) and complicates radio resource management algorithms.

The "S" in TD-SCDMA stands for "synchronous", which means that uplink signals are synchronized at the base station receiver, achieved by continuous timing adjustments. This reduces the interference between users of the same timeslot using different codes by improving the orthogonality between the codes, therefore increasing system capacity, at the cost of some hardware complexity in achieving uplink synchronization.

## **2.3 Wireless Transmission Protocols**

There are several transmission protocols in wireless manner to achieve different application-oriented tasks. Below, some of these applications are given.

### **2.3.1 Wireless Local Loop (WLL) and LMDS**

Microwave wireless links can be used to create a wireless local loop. The local loop can be thought of as the "last mile" of the telecommunication network that resides between the central office (CO) and the individual homes and business in close proximity to the CO. An advantage of WLL technology is that once the wireless equipment is paid for, there are no additional costs for transport between the CO

and the customer premises equipment. Many new services have been proposed and this includes the concept of Local Multipoint Distribution Service (LMDS), which provides broadband telecommunication access in the local exchange.

### **2.3.2 Bluetooth**

Facilitates ad-hoc data transmission over short distances from fixed and mobile devices as shown below.

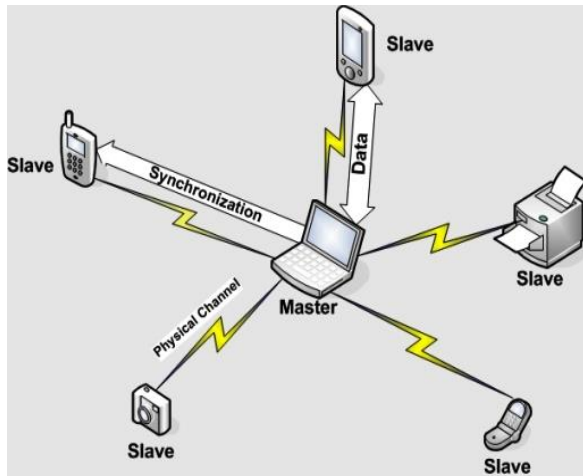


Figure 2.1: Data transmission with Bluetooth technology

Uses a radio technology called frequency hopping spread spectrum. It chops up the data being sent and transmits chunks of it on up to 79 different frequencies. In its basic mode, the modulation is Gaussian frequency shift keying (GFSK). It can achieve a gross data rate of 1 Mb/s. Primarily designed for low power consumption, with a short range (power class-dependent: 1 meter, 10 meters, 100 meters) based on low-cost transceiver microchips in each device.

### 2.3.3 Wireless Local Area Networks (W-LAN)

IEEE 802.11 WLAN uses ISM band (5.275-5.825GHz)

Uses 11Mcps DS-SS spreading and 2Mbps user data rates (will fallback to 1Mbps in noisy conditions)

IEEE 802.11a standard provides up to 54Mbps throughput in the 5GHz band. The DS-SS IEEE 802.11b has been called Wi-Fi. Wi-Fi networks have limited range. A typical Wi-Fi home router using 802.11b or 802.11g with a stock antenna might have a range of 32 m (120 ft) indoors and 95 m (300 ft) outdoors.

Range also varies with frequency band.

IEEE 802.11g uses Complementary Code Keying Orthogonal Frequency Division Multiplexing (CCK-OFDM) standards in both 2.4GHz and 5GHz bands.

### 2.3.4 WiMax

Provides up to 70 Mb/sec symmetric broadband speed without the need for cables. The technology is based on the IEEE 802.16 standard (also called WirelessMAN)

WiMAX can provide broadband wireless access (BWA) up to 30 miles (50 km) for fixed stations, and 3 - 10 miles (5 - 15 km) for mobile stations. In contrast, the WiFi/802.11 wireless local area network standard is limited in most cases to only 100 - 300 feet (30 - 100m)

The 802.16 specification applies across a wide range of the RF spectrum, and WiMAX could function on any frequency below 66 GHz (higher frequencies would decrease the range of a Base Station to a few hundred meters in an urban environment).

### 2.3.5 Zigbee

ZigBee is the specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4-2006 standard for wireless personal area networks (WPANs), such as wireless headphones connecting with cell phones via short-range radio.

This technology is intended to be simpler and cheaper. ZigBee is targeted at radio-frequency (RF) applications that require a low data rate, long battery life, and secure networking.

ZigBee operates in the industrial, scientific and medical (ISM) radio bands; 868 MHz in Europe, 915 MHz in countries such as USA and Australia, and 2.4 GHz in most worldwide.

### 2.3.6 Wibree

Wibree is a digital radio technology (intended to become an open standard of wireless communications) designed for ultra low power consumption (button cell batteries) within a short range (10 meters / 30 ft) based around low-cost transceiver microchips in each device.

Wibree is known as Bluetooth with low energy technology.

It operates in 2.4 GHz ISM band with physical layer bit rate of 1 Mbps.

## 2.4 Mobile Computing Advantages

The following are the advantages of mobile computing: -

- i. **Location Flexibility:** You no longer need to stay plugged in (literally!) to a specific location for performing computing activities. Mobile computing allows you unprecedented flexibility to move about and perform computing activities at the same time! This is, indeed, the chief among all other benefits of portable computing. Traveling abroad for work and missing family and friends? Mobile computing enables you to connect with near and dear ones while you're in transit, thanks to evolution of the mobile technology!
- ii. **Saves Time:** Doesn't it get boring when you're on a 12 hour-long flight across the globe? Don't you feel you could use some of these 12 hours to get some office work done? Mobile computing technology is just the thing to use such transit time more effectively! It also allows to instantly connect with your family anywhere and anytime. Missing your parents during the college tour? Not any more! You can connect with them over Internet using portable computing devices such as Internet phones and share the fun!
- iii. **Enhanced Productivity:** Increased work flexibility is directly proportionate to enhanced work productivity - the fact that you can do your work from any place you want, without waiting for, and making efforts to, get access to computing facility translates into people being able to do more work with greater flexibility. This is the reason why most companies these days offer home-computing access to employees. Suppose a national emergency is declared or any natural calamity occurs (or any other reason) due to which offices stay closed, work can still go on as people are no longer dependent upon office computing systems to get their work done!
- iv. **Ease of Research:** Mobile computing and the flexibility offered by it enable students as well as professionals to conduct in-depth research on just about any topic or subject even when on the go!
- v. **Entertainment:** Nowadays, with the advent and advance of mobile communication technology, no time is wasted anymore! Getting bored is so last-decade now what with zillions of entertainment options available on mobile communication and computing devices these days - games, movies, music, videos, you name it!
- vi. **Improved decision making:** Mobile Computing lets you conduct business at the point of activity. The ability to collect, access and evaluate critical business information quickly and accurately means better decision making that can have a far-reaching effect on your company's ability to compete successfully



- vii. **Improved customer relations:** The success of a business can often be measured by its ability to satisfy customers. Mobile computers gives your field worker the ability to answer customer questions, check order status and provide other services anytime their customers need them from wherever they happen to be.

## 2.5 Limitations of mobile computing

The following are the limitations of mobile computing: -

- i. **Insufficient bandwidth:** Mobile Internet access is generally slower than direct cable connections, using technologies such as GPRS and EDGE, and more recently HSDPA and HSUPA 3G networks. These networks are usually available within range of commercial cell phone towers. Higher speed wireless LANs are inexpensive but have very limited range.
- ii. **Security standards:** When working mobile, one is dependent on public networks, requiring careful use of VPN. Security is a major concern while concerning the mobile computing standards on the fleet. One can easily attack the VPN through a huge number of networks interconnected through the line.
- iii. **Power consumption:** When a power outlet or portable generator is not available, mobile computers must rely entirely on battery power. Combined with the compact size of many mobile devices, this often means unusually expensive batteries must be used to obtain the necessary battery life.
- iv. **Transmission interferences:** Weather, terrain, and the range from the nearest signal point can all interfere with signal reception. Reception in tunnels, some buildings, and rural areas is often poor.
- v. **Potential health hazards:** People who use mobile devices while driving are often distracted from driving and are thus assumed more likely to be involved in traffic accidents. (While this may seem obvious, there is considerable discussion about whether banning mobile device use while driving reduces accidents or not.) Cell phones may interfere with sensitive medical devices. Questions concerning mobile phone radiation and health have been raised.
- vi. **Human interface with device:** Screens and keyboards tend to be small, which may make them hard to use. Alternate input methods such as speech or handwriting recognition require training.

## 2.6 Portable computing devices

The following is a list of mobile computing devices: -

- i. A **portable computer** is a general-purpose computer that can be easily moved from place to place, but cannot be used while in transit, usually because it requires some "setting-up" and an AC power source. The most famous example is the Osborne 1. Portable computers are also called a "transportable" or a "luggable" PC.
- ii. A **tablet computer** that lacks a keyboard (also known as a non-convertible tablet) is shaped like a slate or a paper notebook. Instead a physical keyboard it has a touchscreen with some combination of virtual keyboard, stylus and/or handwriting recognition software. Tablets may not be best suited for applications requiring a physical keyboard for typing, but are otherwise capable of carrying out most of the tasks of an ordinary laptop.
- iii. A **personal digital assistant (PDA)** is a small, usually pocket-sized, computer with limited functionality. It is intended to supplement and to synchronize with a desktop computer, giving access to contacts, address book, notes, e-mail and other features.

- iv. A PDA with a web browser is an **Internet tablet**, an Internet appliance in tablet form. It does not have as much computing power as a full tablet computer and its applications suite is limited, and it cannot replace a general-purpose computer. Internet tablets typically feature an MP3 and video player, a web browser, a chat application and a picture viewer.
- v. An **ultra-mobile PC** is a full-featured, PDA-sized computer running a general-purpose operating system.
- vi. A **smartphone** has a wide range of features and installable applications.
- vii. A **carputer** is installed in an automobile. It operates as a wireless computer, sound system, GPS, and DVD player. It also contains word processing software and is bluetooth compatible.
- viii. A **Fly Fusion Pentop Computer** is a computing device the size and shape of a pen. It functions as a writing utensil, MP3 player, language translator, digital storage device, and calculator.
- ix. A **laptop computer** is a personal computer for mobile use. A laptop utilizes most of the same components as a desktop computer, including a display, a keyboard, a pointing device such as a touchpad (also known as a trackpad) and/or a pointing stick, and speakers into a single unit. A laptop is powered by mains electricity via an AC adapter, and can be used away from an outlet using a rechargeable battery. Laptops are also sometimes called notebook computers, notebooks or netbooks.
- x. **Netbooks** are a category of small, lightweight, legacy-free, and inexpensive laptop computers. At their inception in late 2007 as smaller notebooks optimized for low weight and low-cost netbooks omitted certain features (e.g., the optical drive), featured smaller screens and keyboards, and offered reduced computing power when compared to a full-sized laptop. Over the course of their evolution, netbooks have ranged in size from below 5" screen diagonal to 12". A typical weight is 1 kg (2–3 pounds). Often significantly less expensive than other laptops. In the short period since their appearance, netbooks grew in size and features, and converged with smaller, lighter notebooks and subnotebooks. By August 2009, when comparing a Dell netbook to a Dell notebook, CNET called netbooks "nothing more than smaller, cheaper notebooks," noting, "the specs are so similar that the average shopper would likely be confused as to why one is better than the other," and "the only conclusion is that there really is no distinction between the devices. "However, by 2011, the increasing popularity of tablet computers, particularly the iPad, had led to a decline in netbook sales.

### Revision questions

- i. How has mobile communication evolved over time
- ii. Which technologies are used in mobile communication?
- iii. What are the advantages and challenges of using mobile technologies?
- iv. Describe the various devices used mobile communication