The theory of electromagnetic radiation was propounded by Clark Maxwell in 1857 and explained mathematically the behaviour of electromagnetic waves. Then G. Marconi invented transatlantic radio transmission using electromagnetic waves in 1901. However, as the bandwidth of these transmission systems was very small, the transmission of information was very slow.

Though the electromagnetic waves were first discovered as a communications medium at the end of the 19th century, these were put in use for the masses very late. The first systems offering mobile telephone service (car phone) were introduced in the late 1940s in the US and in the early 1950s in Europe. These single-cell systems were severely constrained by restricted mobility, low capacity, limited service, and poor speech quality. Also the equipment was heavy, bulky, expensive, and susceptible to interference.

The first generation
1G mobile phones were based on the analogue system. The introduction of cellular systems in the late 1970s was a quantum leap in mobile communication, especially in terms of capacity and mobility. Semiconductor technology and microprocessors made smaller, lighter, and more sophisticated mobile systems a reality. However, these 1G cellular systems still transmitted only analogue voice information.

The prominent ones among 1G systems were advanced mobile phone system (AMPS), Nordic mobile telephone (NMT), and total access communication system (TACS). With the introduction of 1G phones, the mobile market showed an annual growth rate of 30 to 50 per cent, rising to nearly 20 million subscribers by 1990.

The second generation
2G phones using global system for mobile communications (GSM) were first used in the early 1990s in Europe. GSM provides voice and limited data services, and uses digital modulation for improved audio quality.

Multiple digital systems. The development of 2G cellular systems was driven by the need to improve transmission quality, system capacity, and coverage. Further advances in semiconductor technology and microwave devices brought digital transmission to mobile communications.

Speech transmission still dominates the airways, but the demand for fax, short message, and data transmission is growing rapidly. Supplementary services such as fraud prevention and encryption of user data have become standard features, comparable to those in fixed networks.

2G cellular systems include GSM, digi-
tional AMPS (D-AMPS), code-division multiple access (CDMA), and personal digital communication (PDC).

Today, multiple 1G and 2G standards are used in worldwide mobile communications. Different standards serve different applications (paging, cordless telephony, wireless local loop, private mobile radio, cellular telephony, and mobile satellite communication) with different levels of mobility, capability, and service area. Many standards are used only in one country or region, and are incompatible.

GSM is the most successful family of cellular standards. It includes GSM900, GSM-railway (GSM-R), GSM1800, GSM1900, and GSM400. GSM supports around 250 million of the world’s 450 million cellular subscribers, with international roaming in approximately 140 countries and 400 networks.

The core network. This network links together all the cells into a single network, coordinates resources to hand over your call from one cell to another as you move, discovers where you are so that you can receive incoming calls, links to the fixed-line phones, and communicates with roaming partners. You can use your phone on other network links to the Internet, so you can reach Web servers and corporate networks. Working on the basis of e-mails, it sends text and graphics-rich data as packets at very fast speed.

The circuit-switched technology has a long and successful history but it is inefficient for short data transactions and always-on service. The packet-switched technology gains importance with the rise of the Internet and Internet protocol (IP). But as IP too has its own weaknesses, circuit-switched services are not going to disappear.

Transmission control protocol (TCP) provides a virtual end-to-end connection for reliability. Although Telnet is still used as a standard protocol for remote access to computer hosts, the main protocols in use today are HTTP for Web servers, SMTP for e-mail, and SNMP for network management.

The GPRS (2.5G) core network and service characteristics. Although GPRS is an extension to the radio access network, it requires whole new packet-based IP data links, servers, and gateways in the core network. Thus GPRS adds several new components besides changing the existing GSM or TDMA network.

GPRS is important because it helps operators, vendors, content providers, and users prepare for 3G, as many concepts of GPRS live on in 3G, and we will need these enhancements to 2G networks for ten years or more.

At the moment, wireless network technologies are somewhere between 2G and 2.5G. The second generation of mobile communications technology was all about digital PCS. The problem, however, was that much of the digital network was implemented for, or overlaid onto, proprietary networking equipment. Taken together, 2G and 2.5G technologies are far from seamless. These range from spread-spectrum code-division multiple access (CDMA) in North America to narrow-spectrum time-division multiple access (TDMA) and GSM in Europe and Asia. In addition to these incompatibilities, both systems offer digital voice at a relatively low speed with very little bandwidth left over for data.

The third generation

The 3G technology adds multimedia facilities to 2G phones by allowing video, audio, and graphics applications. Over 3G phones, you can watch streaming video or have video telephony. The idea behind 3G is to have a single network standard instead of the different types adopted in the US, Europe, and Asia. These phones will have the highest speed of up to 2 Mbps, but only indoors and in stationary locations.
mode. With high mobility, the speed will drop to 144 kbps, which is only about three times the speed of today's fixed telecom modems.

3G cellular services, known as Universal Mobile Telecommunications System (UMTS) or IMT-2000, will sustain higher data rates and open the door to many Internet style applications. The main characteristics of IMT-2000 3G systems are:

Siemens SX45 UMTS phone

1. A single family of compatible standards that can be used worldwide for all mobile applications.
2. Support for both packet-switched and circuit-switched data transmission.
3. Data rates up to 2 Mbps (depending on mobility).
4. High spectrum efficiency.

IMT-2000 is a set of requirements defined by the International Telecommunications Union (ITU). ‘IMT’ stands for International Mobile Telecommunications, and ‘2000’ represents both the scheduled year for initial trial systems and the frequency range of 2000 MHz.

The most important IMT-2000 proposals are the UMTS (W-CDMA) as the successor to GSM, CDMA2000 as the successor to interim-standard ’95 (IS-95), and time-division synchronous CDMA (TD-SCDMA) and UWC-136/EDGE as TDMA-based enhancements to D-AMPS/GSM—all of which are leading previous standards towards the ultimate goal of IMT-2000.

UMTS increases transmission speed to 2 Mbps per mobile user and establishes a global roaming standard. Fig. 1 shows the 3G network perspective.

UMTS is a so-called 3G, broadband standard for packet-based transmission of text, digitised voice, video, and multimedia at data rates up to and possibly higher than 2 Mbps, offering a consistent set of services to mobile computer and phone users, no matter where they are in the world. Based on the GSM communication standard, UMTS, endorsed by major standards bodies and manufacturers, allows mobile users to have the constant access to the Internet and the same set of capabilities irrespective of their location. Users gain access through a combination of terrestrial wireless and satellite transmissions.

Until UMTS is fully implemented, users can have multi-mode devices that switch to GPRS or EDGE technology where UMTS is not yet available.

Today’s cellular telephone systems are mainly circuit-switched type, with connections always dependent on the circuit availability. With UMTS, the packet-switched connection using the IP means that a virtual connection is always available to any other end point in the network. This makes it possible to provide new services such as alternative billing methods (pay-per-bit, pay-per-session, flat rate, symmetric bandwidth, and others). The higher bandwidth of UMTS also promises video conferencing and the virtual home environment. In virtual home environment, a roaming user can have the same services as at home or in the office, through a combination of transparent terrestrial and satellite connections. Fig. 2 shows the difference between regular CDMA and W-CDMA.

3G promises increased bandwidth, up to 384 kbps when the device holder is walking, 128 kbps in a car, and 2 Mbps in fixed applications. In theory, 3G would work over North American as well as European and Asian wireless air interfaces. A new air interface called enhanced data...
GSM environment (EDGE) has been developed specifically to meet the bandwidth needs of 3G. EDGE is a faster version of GSM wireless service.

But the outlook for 3G is neither clear nor certain. Part of the problem is that network providers in Europe and North America currently maintain separate standards bodies. In addition to technical challenges, there are financial issues that cast a shadow over 3G’s desirability.

FOMA

Launched in October 2001, DoCoMo’s Freedom of Multimedia Access (FOMA) service provides fast, high-quality voice and image transmission through packet-based networks. FOMA’s secure access can be used for mobile banking and e-commerce, e-mail, and i-mode compatible Websites. Its high-speed packet transmission network allows the i-mode structure to handle more multimedia content for 3G and 4G wireless Internet services.

FOMA handsets use user-identity module (UIM) SIM cards. These will be available in three types, namely, Standard (FOMA N2001), Visual (FOMA P2101), and DataCard (FOMA P2401). The FOMA N2001 by Nokia has an improved colour screen and no external antenna. The P2101V by Panasonic takes image stills, so it can function as a TV phone with compatible equipment. Panasonic’s P2401 has a PCMCIA card for high-volume data transmissions.

A group of cellular phone makers, carriers, and software developers had announced the so-called ‘open mobile architecture’ that would support two basic air-interface standards, namely, GSM/GPRS and W-CDMA. But some companies didn’t agree with the proposal.

However, mobile phone designs adopting a common architecture are gaining momentum.

The main reason for this trend is microcontrollers executing application software for processing moving pictures, music, and other data. Microcontroller manufacturers like Texas Instruments and Intel Corp. are collaborating with handset manufacturers in Taiwan and China. Such handsets, when produced in large volumes, will cost lower than the existing handsets. Thus, Texas Instruments and Intel Corp. are expected to become the main players in the global mobile industry.

The fourth generation

4G mobile communications will have transmission rates up to 20 Mbps—higher than 3G. The technology is expected to be available by the year 2010. Presently, NTT DoCoMo and Hewlett-Packard are on their agenda to make it available by the year 2006.

4G is being developed with the following objectives:

1. Speeds up to 50 times higher than 3G. However, the actual available bandwidth of 4G is expected to be about 10 Mbps.

2. Three-dimensional virtual reality—imagine personal video avatars and realistic holograms, and the ability to feel as if you are present at an event even if you are not. People, places, and products will be able to interact as the cyber and real worlds merge.

3. Increased interaction between corroborating technologies; the smart card in your phone will automatically pay for goods as you pass a linked payment kiosk, or will tell your car to warm up in the morning as your phone has noted you leaving the house.

Ericsson and the University of California are jointly researching CDMA wireless access technology, advanced antenna systems, next-generation mobile Internet, quality of service, power amplifier technology, and wireless access networks.

Other 4G applications include high-performance streaming of multimedia content based on agent technology and scaleable media coding methods. 4G will solve problems like limited bandwidth in 3G when people are moving and uncertainty about the availability of bandwidth for streaming to all users at all times.

One of the key requirements is to realise a wireless 4G IP-based access system. The ultimate objective is to create a protocol suite and radio communication schemes to achieve broadband mobile communication in 4G wireless systems. A new protocol suite for 4G wireless systems supported by Department of Defense (DoD) contains:

1. Transport-layer protocols
2. Error-control protocols
3. Medium-access protocol
4 Mobility management
5 Simulation testbed
6 Physical testbed
7 Protocol suite in the mobile terminal (Fig. 3(a))
8 Protocol suite in the base station (Fig. 3(b))

4G technology concerns
One of the main concerns about 4G is that due to high speed of the frequency, it will experience severe interference from multipath secondary signals reflecting off other objects. To counter this problem, a number of solutions have been proposed, including use of a variable spreading factor and orthogonal frequency code-division multiplexing.

Next comes the problem of non-compatibility of various applications. For example, FOMA-enabled videophones cannot be used for i-motion music and video links; and the N2002 handset erases parts of the phone’s memory if certain Websites are accessed.

Finally, as i-mode mobile phones cost very high, the technology will be limited to corporate use. Nevertheless, following

the Moore’s law and Metcalfe’s law, no one can predict the future. The Moore’s law predicts that the speed and capacity of semiconductor double every 18 months, whereas Metcalfe’s law predicts that the network utility increases with the number of nodes and users.

4G will provide better-than-TV quality images and video-links. The communications model has new developed versions of HTML, Java, GIF, HTTP, and many more. New standards will need to be developed for use in 4G.

Java-based i-mode programs
Variants of Java-based i-mode programs include the i-appli, which downloads maps and displays charts of online information. It also enables remote users to receive automatic notifications of weather, traffic, appointments, etc, both online and from a company intranet. The main bonus for users of this software is the additional security encryption, which makes it suitable for e-commerce and mobile banking. The software has been developed by NTT DoCoMo in conjunction with Sun Microsystems.

i-mode and M-mode
Dubbed 4G, the i-mode technology will offer data transmission rates up to 200 times higher than 2G at 20 Mbps. 3G data rate is currently 2 Mbps, which is very high compared to 2G’s 9.6 kbps. 4G builds on the 3G standard, integrating and unifying the different interfaces (W-CDMA, CDMA2000, EDGE, etc).

The development of 4G expands upon current i-mode technology that has gained wide success in Japan. The streamlined and unified wireless Internet technology works through iHTML to provide a high-quality Web service.

i-mode has speeded up data transmission of up to 40,000 Internet sites for users. Charges are based on the amount of data transmitted rather than the time spent on it.

AT&T has launched the M-mode service tailored to the US market. The service is based on WAP technology, and offers a dual browser with i-mode. Although applications such as cartoons aren’t available, messaging, information services, and entertainment are all accessible for American users.