What is New in Computers?

Mobile Computing

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This article discusses the recent trends in mobile computing and communication. The wireless technologies behind the emergence of mobile computing and the use of the current technologies to create a mobile computing environment have also been discussed.

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Introduction

For the past several years there has been a marked advancement in the field of wireless communication and computing leading to exciting services and technologies replacing the concept of station to station communication by person to person communication. The ultimate goal of wireless communication is to ensure information exchange (voice/data/video) with *anyone*, *anytime* and *anywhere*. This led to the idea of mobile communication where the communicating terminals are not connected physically to any fixed networks. In the first generation wireless system, the service provided was voice only using analog cellular and cordless technologies. The second generation systems followed with both voice and data using digital cellular and cordless technologies. Second generation systems provided mobility and made communication cost lower. Different digital wireless communication standards like GSM (Global System for Mobile Communication) in Europe, AMPS (Advanced Mobile Phone Service) in North America, emerged for wireless communications. The evolution of wireless networks is shown in *Table 1*.

With the development of second generation wireless networks which lowered communication cost, the demand for wireless communication service grew rapidly. To deal with this explosive growth rate of wireless communication users, new technological

Time	Technology	Service
First generation ('70–'80)	Analog cellular/cordless	Wireless voice
Second generation ('80–'90)	Digital cellular/cordless Intelligent base stations Macrocellular/picocellular	Advanced voice/data
Third generation (2000+)	Broader bandwidth Higher frequency spectrum	Integrated voice, data and video

Table 1. Evolution of wireless communication.

breakthroughs were made to increase the capacity by efficient use of the wireless medium. Most of the research and development in wireless communication is focussed on two issues: scarce bandwidth utilisation and complete mobility. With the available bandwidth of the wireless medium, it is difficult to support proliferation of mobile stations. So the focus of research is to increase the supporting capacity of wireless medium.

Complete mobility refers to a situation where a person exchanging information can be located anywhere in the world and can be moving or stationary. Allowing mobility is an important issue. Wireless cellular and satellite communication can provide such mobility with the help of different new location tracking techniques.

The third generation wireless system, which will be the future mobile communication system, tries to integrate all services into a wireless terminal. In this case a wireless terminal is called a *mobile station* which not only exchanges voice and data but also provides services like access to the World Wide Web, computer, facsimile and video.

Growth of wireless communication technologies and development of miniaturisation of portable laptops have led to a new era of the mobile computing. The prime issues focussed are: communication, computing and portability.

A man with a small laptop or a palmtop can now roam around the world at ease if connected to a network (e.g. Internet). He can

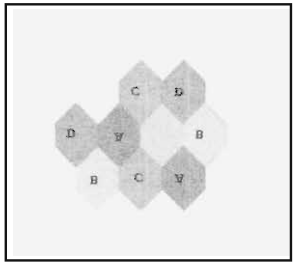

Figure 1. Cellular structure.

send e-mails, fax, videos along with voice. Basically he can access all the Internet resources through his laptop although mobile. A person with a mobile computer has complete flexibility. He can carry all information transaction through his personal laptop when he is on the move. He can access yellow pages, digital libraries and also can set up video conference with other people. Mobile computers can therefore provide a good environment for distance learning, field experiments, and medical collaboration.

Cellular Concept

Nearly all wireless based personal communication systems use the cellular concept. In a cellular system, a geographical area supporting wireless communication is divided into a number of cells (*Figure 1*). Each cell has a base station (BS) as shown in *Figure 2*. A person who has a wireless terminal (e.g., a mobile phone) tries to make/receive a call, a connection is set up between him and the base station of the cell in which he is located (shown by dotted lines in *Figure 2*).

The base station may be connected to a worldwide PSTN (Public Switched Telecommunication Network) or ISDN (Integrated Service Digital Network). PSTN and ISDN provide the wire-line infrastructure which is the telephone network.

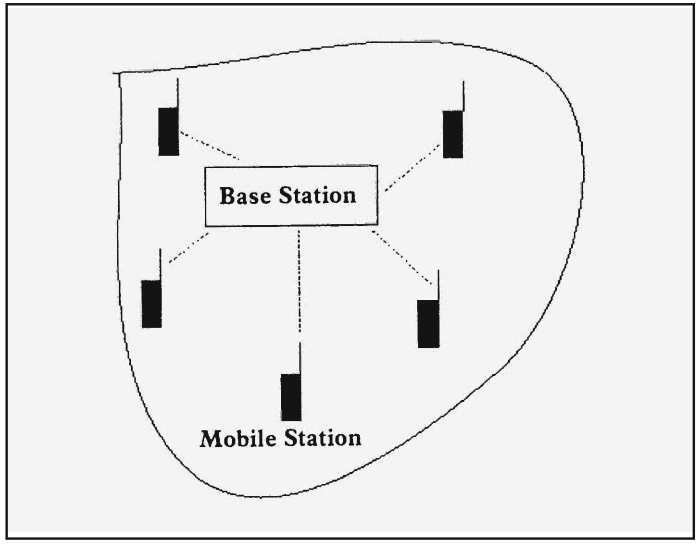

Figure 2. Inside a cell.

In a cellular system whenever a person moves from one cell to another, he gets disconnected from the base station of the current cell and is connected to the base station of the cell to which he has moved.

There are many good reasons why wireless communication uses the cellular concept. Some of these are given in the next section.

The cellular approach supports more mobile stations by a technique called frequency reuse.

Advantages of Cellular Concept

The cellular approach supports more mobile stations by a technique called frequency reuse. The radiated energy of mobile stations is kept at a value such that the same frequency can be used in non-adjacent cells without causing any interference. In *Figure 1* we observe that in cells marked A, the same frequency can be used for transmission. One must, however, be careful to separate cells using the same frequency to avoid *co-channel interference* between signals from those cells.

The cellular concept also provides more flexibility in supporting different density of traffic by using a technique called *cell splitting*. Let us consider a cell which can support N mobile stations. If after some days the number of mobile stations increases in that cell, then one can split the cell into more smaller cells so that more traffic can be supported by frequency reuse.

We see that the cell boundaries are flexible and dependent on the density of mobile traffic present. Decreasing the cell size will lead to more frequency reuse and hence will support more mobile terminals but in a sparse traffic scenario this is not cost effective since one has also to install more base stations. There is also a limitation set by the co-channel interference.

Operation of Wireless Mobile System

Cell boundaries are flexible and dependent on the density of mobile traffic present.

Mobility Management: The mobility management scheme supports automatic roaming of a terminal which means that a person need not bother about his location. The main problem is to track a person and route a call intended for him.

The tracking of a mobile station is done by two operations: location update and paging.

The tracking of a mobile station is done by two operations: location update and paging. In the most general scenario the overall system is divided into location areas. When a user enters a new location area, he sends a location update information about his new location to the base station. This information is used to update two directories: VLR (visitor location register), HLR (home location register). Both these directories are referred to while tracking the mobile terminal.

Each of these location areas consists of several cells. The location update operation may be triggered at some interval of time. In the update procedure, the base station broadcasts continuously the identity of the location area. Hence, whenever the mobile terminal detects a difference in the location by monitoring the broadcast channel on which the base station sends, it reports the new location to the base station.

When a call is destined for a mobile terminal, the location registers are consulted to find the exact location area of the terminal. Once the call reaches the proper location area, paging is performed to track the terminal. In paging, basically the identity of the user for whom the call is intended is broadcasted. On hearing this broadcast the specific terminal responds and a connection is set up between the base station and the mobile terminal.

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Usually each mobile terminal (say phone) has a fixed address/ registration number and a temporary roaming number. Each time the mobile terminal enters a new location area, the VLR associated with that location area assigns a roaming number (also called MSRN, mobile station roaming number) to the terminal. This number is then entered into the HLR. From the fixed PTN (public telephone number), the user's HLR is identified and from the HLR the user's current location area address is found out. The MSRN is then subsequently used to page the mobile user and alert him for receiving the call.

Location tracking strategies help the user in supporting mobility

to the terminal. There arises another problem when a mobile terminal moves from one cell to another cell.

Wireless Hand-off: Switching from one cell to another cell needs disconnection from previous base station and making a new connection with the current base station. This operation is called *hand-off*. In *Figure 3* we observe a hand-off taking place. The previous connection between the mobile unit and the base station is shown by a continuous line and the current connection by a dotted line. There are a lot of hand-off strategies to perform cell to cell switching. But whatever be the hand-off strategy the user must not face any interruption or degradation in the quality of communication when the hand-off takes place. This implies that the hand-off operation must be transparent to the mobile users.

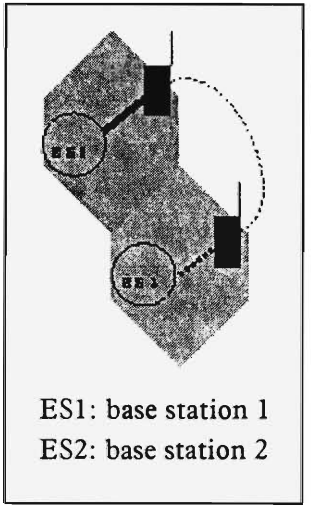

Figure 3. Cell hand-off.

There are two types of hand-off strategies: hard hand-off and soft hand-off. In hard hand-off if a station is connected to a base station BS1 and is moving to another cell with base station BS2, then first the connection with BS1 is broken and a new connection with BS2 is set up. The reverse happens in the case of soft hand-off, both of them have their own disadvantages. Hard hand-off may lead to a considerable time of disconnection when the mobile user is not connected to any of the base stations. In the soft hand-off, a different problem may occur. When the mobile network is connected to both the base stations and there is a transmission from both to the mobile host, the messages get garbled.

The mobile terminal also needs to know when it should initiate hand-off. This is mostly done by monitoring the received signal strength (RSS) from the base station. If the terminal finds that the RSS from the current base station is lower than either some preset value or the RSS of some other base station, then it initiates a hand-off.

While at hand-off the user gets a new connection with another BS, he must also get the same services from the new BS which he

Given a wireless medium with limited bandwidth, how to make the best use of it is the issue addressed by different multiple access schemes.

was getting from the old BS. This is taken care of in the execution stage of the hand-off. Generally all the hand-over calls are high priority calls and are always given service since no one wants a forced termination of an ongoing call (by hand-over call we mean the call during which a hand-off takes place).

Multiple Access Schemes: The cellular approach supports more users by frequency reuse. Given a wireless medium with limited bandwidth, how to make the best use of it is the issue addressed by different multiple access schemes.

These schemes basically deal with the channel assignment and access protocols. Generally in wireless communication, we call the channel used for transmission from BS to mobile user as down-link broadcast channel and the channel from the mobile user to the base station as up-link multiple access channel.

We find that in the up-link traffic, all the mobile users compete among themselves to make use of the channel to send information. Different multiple access schemes basically provide a rule which must be followed by all users while sending data so that the overall performance improves. By overall performance we mean that the *throughput* must increase and the delay in sending a message must be within a finite limit. Throughput of the system is defined by the amount of data that is sent from one user to another user in a unit time. By delay we mean the average time required for the successful delivery of the data to the destination.

A good multiple access scheme should also be able to handle different types of service like voice, data and video communication. The well known multiple access schemes used are FDMA, TDMA, and CDMA where the channel is shared on the basis of frequency or time or code.

In Time Division Multiple Access, the time is divided into cycles of equal length and each cycle is composed of say N slots of equal width.

TDMA: In TDMA (Time Division Multiple Access), the time is divided into cycles of equal length and each cycle is composed of say N slots of equal width. Every user is given a slot in every cycle. This slot can be kept by the user until the end of the connection. So we see that this scheme can at most support N users if there

are N slots in one cycle. TDMA based protocols are used in cellular systems like GSM based systems in Europe. TDMA scheme provides flexibility in allotment of slots to a user. If a user has more data to send he can get more slots per cycle. TDMA scheme is good for integration of voice and data.

In Frequency Division Multiple Access a unique frequency channel is assigned to each user.

FDMA: In FDMA (Frequency Division Multiple Access), a unique frequency channel is assigned to each user. This channel cannot be used by others even though it is idle. FDMA scheme is used in first generation cellular system. FDMA is unsuitable for high capacity services like multimedia etc.

In GSM based systems, a combination of TDMA and FDMA is used. In GSM, the total wireless bandwidth allocated is 25MHz. Using FDMA, the total frequency band of 25 MHz is divided into 124 carrier frequencies where each carrier frequency serves 200 kHz bandwidth. One or more of these carrier frequencies will then be assigned to the base station. Each of these carrier frequencies is then divided in time, using TDMA scheme, into eight time slots. One time slot is used for transmission and one for reception by the mobile system.

CDMA: In a Code Division Multiple Access system (CDMA), a narrow-band message signal is multiplied by a very large bandwidth signal called spreading signal. This results in broadening of the message signal. In CDMA, all users who want to transmit have their own pseudo-random codeword which forms the spreading signal. All users can transmit simultaneously. In the receiver side, the receiver performs a decoding operation by using the codeword used by the transmitter to get the actual message. There are certain advantages of using CDMA scheme. Firstly many users can share the same carrier frequency having different codewords. Secondly this scheme is more immune to noise.

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Architecture of a Mobile Network

Mobile Station: A mobile station consists of a radio transceiver, display and digital signal processor and a smart card called the

Aloha/CSMA Protocol

Aloha protocol was first developed and implemented at the University of Hawaii in their campus-wide computer networks. In Aloha protocol each computer uses the complete bandwidth of the common channel when it has data to send. In pure Aloha protocol, whenever a computer has data to send, it never waits and sends its data across the channel. The problem is that when more than one user tries to use the channel to send data at the same time, the data gets garbled and eventually gets lost. To reduce this collision , a better version of this Aloha Protocol called slotted Aloha was then developed. In this scheme, one can send his data only at the beginning of a slot.

Subsequent modification of slotted Aloha scheme like CSMA (carrier sense multiple access) has found out better ways of avoiding collision and improving overall performance. In CSMA schemes, the transmitter monitors the channel or medium. In case it detects that someone else is already using the channel, it stops transmitting.

Subscriber Identity Module (SIM). The SIM provides personal mobility, so that the user can have access to all subscribed services irrespective of both the location of the terminal and the use of a specific terminal. By inserting the SIM card into another cellular phone, the user is able to receive calls at that phone, make calls from that phone, or receive other services. The SIM card may be protected against unauthorised use by a password or personal identity number.

Base Station Subsystem: The Base Station Subsystem is composed of two parts, the Base Transceiver Station (BTS) and the Base Station Controller (BSC). The Base Transceiver Station houses the radio transceiver that defines a cell and handles the radio-link protocols with the Mobile Stations. In a large urban area, there will potentially be a large number of BTSs deployed. The requirements for a BTS are ruggedness, reliability, portability, and minimum cost. The base station controller manages the radio resources for one or more BTSs. It handles radio channel setup, frequency hopping, and handover. The BSC also translates the 13kbps voice channel used over radio-link to the standard 64kbps channel used by PSTN or ISDN.

Network Subsystem: The central component of the Network Subsystem is the Mobile Service Switching Centre (MSC). It acts like a normal switching node of PSTN or ISDN, and in addition provides all the functionality needed to handle a mobile subscriber, such as registration, authentication, location updating, hand-overs, and call routing to roaming subscriber. The MSC provides the connection to the public fixed network (PSTN or ISDN).

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Wireless Radio Link: The International Telecommunication Union (ITU) which manages the international allocation of the radio spectrum allocates bands for uplink (mobile station to base station) and downlink (base station to mobile stations).The available spectrum is used for sending data and also for sending control signals. Control signals are sent through dedicated control channels. The control channels include:

Broadcast Control Channel: On this channel the base stations continuously broadcast the base station identity, frequency allocations, and frequency hopping sequences (explained later).

Stand-alone Dedicated Control Channel: This channel is used for registration, authentication, call setup and location updating.

Random Access Channel: This is also called the slotted Aloha channel used for sending the request to use the data channel.

Speech Coding: Presently all wireless based systems use digitised speech signals. Usually Pulse Code Modulation (PCM) was the technique used for conversion of analog signal to digital signals. But the output stream of digitised voice signals from PCM has a bandwidth of 64kbps which is too high a rate to be feasible over a wireless link. Therefore new techniques originated to digitise voice signals keeping the speech quality at an acceptable level. Using digitised voice signal helps in integrating data and voice communication over the same channel.

Multipath Equalisation: The radio waves which are used for sending wireless signals get reflected by everything – buildings,

The frequency hopping is necessary in a mobile network because in each cell different frequencies may be used.

hills, cars, airplanes etc. Each of these reflected signals reaches the antenna with a different phase leading to interference, due to which there is alteration in the signal strength leading to multipath fading. Equalisation is used to extract the desired signal from the unwanted reflections. Equalisation works by finding out how a known signal is modified by multipath fading, and constructing an inverse filter to extract the desired signal.

Frequency Hopping: The mobile station has to be frequency agile. This means that the mobile station must be able to transmit and receive on different carrier frequencies. This is also called frequency hopping. The frequency hopping is necessary in a mobile network because in each cell different frequencies may be used and so depending on the cell the mobile station has to select the frequency on which it has to receive or transmit messages.

Discontinuous Transmission: It is always necessary that the power be conserved at the mobile unit. It is observed that a person speaks less than 40 percent of the time in normal conversation. Discontinuous transmission (DTX) is a method which takes advantage of the above fact. In DTX, every mobile unit has a voice activity detector. Whenever this detector senses a silence period, it turns off the transmitter But this detector must also be able to distinguish between noise and voice, considering the background noise which is always there. The above method also helps in better utilisation of the channel. In the silence periods detected, data can be sent over the channel since the channel is free.

Power Control: It is always desirable that both the mobile and the base station operate in the lowest power level in order to reduce the co-channel interference and save battery power. In power control strategy, the mobile station measures the signal strength or the signal quality (based on the Bit Error Ratio) and passes the information to the Base Station Controller. The BSC then decides whether to change the power level.

Authentication and Security: Since the radio medium can be accessed by anyone, authentication of users to prove that they are who they claim to be, is a very important element of a mobile network. Authentication involves two functional entities, the SIM card in the mobile unit, and the Authentication Center (AC). Each subscriber is given a secret key, one copy of which is in the SIM card and the other in the Authentication Center. During Authentication, the AC generates a random number that it sends to the mobile unit. Both the mobile unit and the AC then use the random number, in conjunction with the subscriber's secret key and a ciphering algorithm called A3, to generate a number that is sent back to the AC. If the number sent by the mobile unit is the same as the one calculated by the AC, the subscriber is authenticated.

Mobile Computing

Growth of wireless communication technologies and development of miniaturisation of portable laptops have led to a new era of mobile computing. The prime issues on which there is focus are: communication, computing and portability.

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Mobility Transparency: With a mobile computer with the change in the underlying network, access point remains transparent to a person. For example say a person has an address in a network in IISc and then he moves to Delhi with a laptop for some official purpose. We observe that he is getting connected to a different network in Delhi. But he still receives e-mail, fax etc as he used to receive in IISc. So the user feels as if he is still connected to the network in IISc.

The mobility transparency is done using mobile Internet protocol (IP). This protocol deals with the routing of packets to/from mobile hosts. According to this protocol, every mobile host/ station has a home agent in his home network and a fixed address belonging to the home network.

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Once the mobile host is in a foreign land, it registers to a mobile support station (MSS) and gets a care-of-address which is basically

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the address of the mobile support station. Now whenever the mobile host moves from one location to another, it keeps its current location address informed to its home agent. This is called mobility binding.

Any packet destined for the mobile host comes first to its home agent. The home agent encapsulates or wraps this packet with a new IP (Internet protocol) layer setting the destination address to be the care of address of the mobile host. This encapsulated packet is then sent to the mobile support station to which the mobile host is currently registered. In *Figure 4*, the dotted line shows the virtual connection with source and destination of the packet, the continuous line indicates the route taken by the packet.

Although this way of packet routing takes a longer route, to improve the situation, the sender after knowing the care of address of the mobile host directly sends messages there. But in case it finds that the mobile host has changed its location and its present care of address has changed then the home agent is again contacted to know the exact location of the mobile host.

Communication Aspects: If a mobile computer is going to support multimedia, then we need a very high capacity wireless network. Also a wireless network has a very high bit error rate due to noise, echoes, and interference. The wireless network is also prone to disconnection. These factors can degrade the

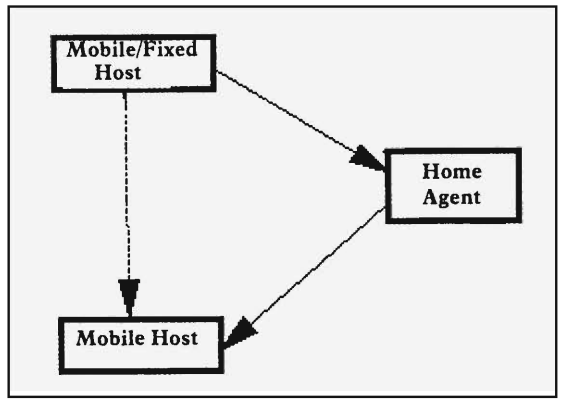

Figure 4. Mobile IP based routing in mobile computing.

performance of the data traffic of a mobile computer. Disconnection is hazardous when a database transaction is going on between mobile computers. Different techniques have been proposed to alleviate these problems. The CODA file system provides a good example of how to handle network disconnection. With CODA, files can be modified even during disconnections. In a mobile computing environment there is great variation in the bandwidth requirements. For video traffic, a huge bandwidth is required, but say for a normal data traffic (like e-mail), much less will do. Also a mobile computer may at times be connected to a high bandwidth fixed network like FDDI or may at other times get connected to lower bandwidth wireless network.

Computing Aspects: The future of mobile computing is not just limited to accessing data over the network, but also towards running real-time applications. Since mobile portable computers have resource crisis in terms of CPU power, memory, and complex system software, they need to interact with powerful stationary computers. Mostly for multimedia based applications, a client-server based interaction model is set up between the mobile host and a stationary host, where a mobile host is the client and the server application runs on a stationary computer. It is also observed that by using location sensitive information, better performance can be obtained. By better performance, we mean that a user sees less delay in the network and also there is better utilisation of the network bandwidth. Location sensitive information means the information about current and future location where the mobile host will be located. By making resources like files, applications, mobile codes follow the mobile user wherever he moves, one can save a lot of network bandwidth and also decrease delay.

Portability Aspects: Today's portable computers are also called PDA (personal digital assistant). We here will discuss certain issues regarding designing of a mobile PDA. It must be small, light, durable, and be operational under wide environmental conditions and should require minimal power.

Research in Mobile Computing

Since last few years a lot of research work is going on in mobile computing at research laboratories in universities and industries. In the mobile computing laboratory at Columbia University, a reconfigurable distributed service which employs a new algorithm that facilitates transactions in spite of disconnection, has been developed. The Mosquito Net Laboratory at Stanford University has developed technologies for seamless switching between different networks, adapting to the changes in network characteristics. Similar work is also going on in the area of Wireless Access Networks at the Bay Area Research Laboratory, University of California, Berkeley.

Suggested Reading

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Since the batteries are the largest single source of weight in a portable computer, minimising power consumption can improve portability by reducing battery weight. Power consumption is proportional to CV^2F, where C is the capacitance of the circuit, V is the voltage swing, and F is the clock frequency. Capacitance can be reduced by better VLSI design. Voltage can be reduced by designing chips which operate at low voltage level. Clock frequency can be reduced but that will also reduce the computational speed. Also secondary storage space must be reduced in a mobile computer, since firstly they are heavy (hard disc) and secondly they consume more power than memory chips. Size constraint in a PDA also needs designing of smaller user interface. It would be cumbersome and uncomfortable for a user to use the normal graphical interface with several windows open and thousands of buttons. To give better user interface, designers are thinking of providing analog input rather than button-click input by using voice recognition methods.

The Future of Wireless Communication

The third generation mobile systems currently under development (also referred as Universal Mobile Telecommunication System UMTS) are trying to achieve a global worldwide universal communication system. UMTS will aim at the integration of different services offered using fixed cordless and mobile networks. To extend the service over more areas like ships, aircrafts, UMTS will have satellite components in addition to terrestrial networks. So we see a future where a user will have unlimited mobility and where he can exchange any type of data from voice to video while on the move. With the rapid growth in the usage of wireless communication and demand for various services, new technological challenges are going to come.

An artist cannot speak about his art any more than a plant can discuss horticulture.

Jean Cocteau