2. Mobile Communication and Emerging Technologies

Article Two on "Mobile and Emerging Technologies" introduces modern communication. It strokes on cellular engineering fundamentals based on radio wave propagation, transmission and reception, and multiple access technique. At the end, emerging technologies, service oriented middleware, and the generation of networks of 1G, 2G, 3G, 4G and Long Term Evolution (LTE) is discussed. The most important takeaway is LTE and the features of the networks beyond 4G.

2.1 Introduction to modern communication

Initial stages of communication involved communication between one pair of users on single channel pair. The strength of the mobile communication was determined by transmitter power, type of antenna used and the frequency of operation. But a great number of users created a problem. To resolve this, cellular communication was developed. To accommodate multiple users, Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and Frequency Division Multiple Access (FDMA) and their hybrids were used.

At the initial stages, mobile communication was restricted to certain users only, and was never meant for use of the common people. However, in 1970s with the connection of mobile users with PSTN, there has been a very good growth in the cellular radio. It is in 1990s, that the government came out with radio spectrum licenses for 1.8 – 2.0 GHz range. 1G was the first generation network that came into picture in the USA in Chicago in 1983 using FDMA / FDD and analog FM. 2G or 2nd generation network brought live three TDMA standards and one popular CDMA network. To support the modern network using internet, 2.5G was developed. It helped in supporting higher data rate transmission, e-mail traffic, and local based mobile service. Then the 3G network, the 3rd generation network, which surpassed 2.5G. This 3rd generation network, enabled network operators to offer advanced services with greater network capacity and through improved spectral efficiency. The advanced services were wide-area wireless voice telephony, video calls and broadband wireless data. The technical requirement of 3G networks included higher data rate transmission, symmetrical and asymmetrical data transmission, circuit switched and packet switched based service, higher speech quality, higher spectral efficiency, concurrent usage, global roaming, and open architecture for rapid introduction of new services and technology.

The advances in telecommunications promoted several protocols in the wireless manner. This included WLL or wireless local loop, Bluetooth, W-LAN or wireless local area network, Wi-Max, Zigbee, Wibree.

Microwave wireless link can be used to create a wireless local loop. This loop can reside in the central office, and the individual homes and business in close proximity. The WLL is advantageous as additional paid efforts are not needed to connect from the central office to the close proximity of customer's equipment. On the other hand, Bluetooth is used to transmit data over fixed and mobile devices, using a radio technology called hopping spread spectrum. It is designed for power consumptions, with a short-ranged connection with a micro-chip in it. Similarly, Wi-Max provides broadband wireless access up to 30 miles (50 kilometres) for the fixed stations and 3-10 miles (5-15 kilometre) of a mobile station. Zigbee is a high-level communication protocol using a small wireless personal network, targeted at a radio frequency that requires a low data rate and long battery life. In the same lines, Wibree is a lower data frequency protocol, which is designed for ultra-low power consumption within a short range of 10 metres (30 feet). It is similar to Bluetooth with low energy technology.

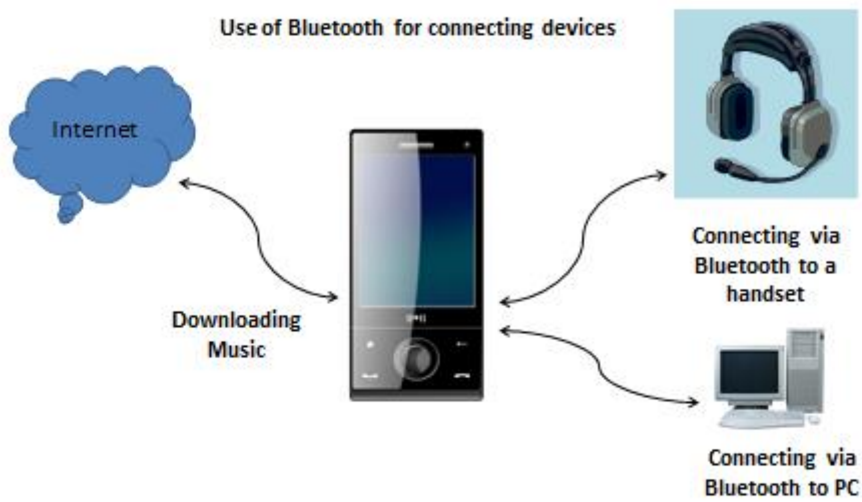

Figure 2.1.1: Use of Bluetooth is to connect to devices with the absence of a physical connectivity.

2.2 Signals & the type of medium

The main objective of the signalling process is to convey a message through a medium. Whether it is collecting statistics from another workstation, or transmitting data through the cables of a workstation, or drumming to convey that there is a danger of fire around in early times, each of these work are actually transmitting signals through the various medium. Hence, there is a system of digital and analogue signals that can be transmitted.

Data can be of both the types- analogue and digital. Human voice is an analogue data. When someone says something, the medium of air waves carry the data over the air. This voice can be recorded again through a voice recorder or transmitted with a mike to make the data digital or analogue. Any form of data in the combination of 0s and 1s is known as digital data. A digital signal can have a set of values against any number of values in an analogue signal. Now, both the digital and analogue signals can be periodic and aperiodic as well. A periodic signal repeats itself over a period, or time. An aperiodic signal does not repeat over any period of time.

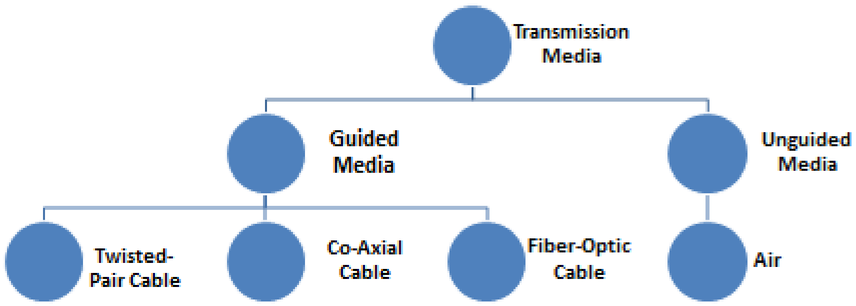

Figure 2.2.1: Types of media for transmission. (Image adapted from "Data communication and networking" by Forouzan, Page 174)

In the types of media for transmission, we have guided and unguided media. In unguided media wireless transmission is made. Again, in the unguided media, there are three types of wireless transmission: radio-wave, microwave and infra-red transmission. The entire frequency spectrum is divided into many parts as shown:

Band	Range	Propagation	Application
Very Low Frequency (VLF)	3-30 KHz	Ground	Long Range Radio
Low Frequency (LF)	30-300 KHz	Ground	Radio Beacons
Middle Frequency (MF)	300 KHz- 3 MHz	Sky	AM Radio
High Frequency (HF)	3-30 MHz	Sky	Ship/ Aircraft Communication
Very High Frequency (VHF)	30-300 MHz	Sky and Line-of-Sight	TV, FM Radio
Ultra High Frequency (UHF)	300 MHz – 3 GHz	Line-of-Sight	Cellular Phones, Paging, Satellite
Super High Frequency (SHF)	3-30 GHz	Line-of-Sight	Satellite Communication
Extremely High Frequency (EHF)	30-300GHz	Line-of-Sight	Radar, Satellite

Figure 2.2.2: Range of frequencies and their applications.

Radio Waves and micro waves do not have any clear-cut difference. Electromagnetic waves ranging from 3 KHz to 1 GHz are called radio waves, while waves ranging from 1 to 300 GHz are called microwaves. Radio waves are along all directions- that means omnidirectional. When antenna transmits waves, it can be in all the directions. This has a slight disadvantage as radio waves transmitted by one antenna can have interference from another antenna. Radio waves which propagate in the sky-mode actually are good selections for the AM radio. Radio waves are used for radio, TV and paging systems.

Microwaves are unidirectional. An antenna can be narrowly focussed. Hence, there is a less chance of interference. Microwave propagation can be of line-of-sight. Since the towers of mounted antennas need to be along the line of sight of each other, towers supporting the infrastructure need to be tall, taking into account the curvature of the earth. Microwaves can be used for cellular telephones, satellite network, and wireless LANs.

Infrared band with frequencies from 300 GHz to 400 THz can be used for short-range communications. Infrared signals cannot penetrate walls, and hence the remote used by one room can never have any interference with another in the other room. Infrared signals can be used for short ranged communications.

Cellular telephone is designed to provide inter-communication between two moving units, named as mobile stations, or between one stationary unit and the other fixed unit called Land Line. A service provider must be able to locate and track a calling unit, delegate a channel to the call, and transfer the channel from one base station to a different base station if the caller or receiver moves out of range. To track a device, each service area is divided into cells. Again, each cell has antenna and is controlled by base station. Each base station is controlled by a switching office, known as mobile switching centre (MSC). MSC co-ordinates communication between two or more base stations and the telephone central office.

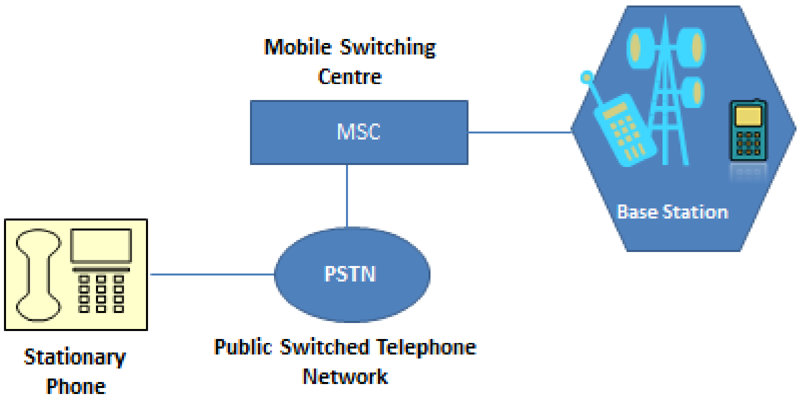

Figure 2.2.3: Cellular System

The cellular system works as mentioned. The stationary phone calls the public switched telephone network (PSTN), which is connected to mobile switching centre (MSC), and this is connected to the base station as shown. The base station relays the information within the cell to the handset as shown. This is the fundamental behind a cellular system.

2.3 Cellular Engineering fundamentals

For the effective use of the radio spectrum, coupled with the increasing subscriber base, channel assignment strategies were used, mainly fixed and dynamic.

In fixed channel assignment, a fixed number of voice channels are linked to each cell. Any communication within the cells can be made with the help of the unused channels. Practically, if the channel is occupied, then the call is blocked. Another development allowed a borrowing from the adjacent cell, if all the cells are occupied. This is called the borrowing strategy.

In dynamic channel assignment, the channels are temporarily assigned to the cell for usage. Allocation of a channel is done for the call requested to the base station, which gets forwarded to Mobile Switching Centre (MSC). Comparatively, the dynamic channel assignment has reduced probability of blocking, and the trunking capacity is allowed in all the cells. One drawback is that this assignment puts a heavy load in congestion of calls.

When a user moves from one place to another, the user changes the base station. To keep the call uninterrupted, automatic transfer is done using the change of FDD channel. This process is called handoff. The following factors influence the handoff process: transmitted power and received power.

Some practical problems associated with the mobile handoff process are: different speed of mobile users, cell dragging issues, and inter-system handoff. Another problem associated with the telecommunication system is interference and system capacity. These problems arise with the time-congestion within the electromagnetic spectrum. If there is interference, noises can be heard. Interference is more in the urban areas as the tele-density is more. They can again be divided into co-channel and inter-channel interference.

To effectively use the spectrum, it is necessary to re-use the limited bandwidth. However, this method increases interference, which decreases system capacity and service quality. Co-channel interference allows cross-talks between two radio transmitters. This type of interference is caused by channels in adjacent cells. It is a signal impairment that happens when imperfect receiver filters allow nearby frequencies to leak into the pass band. This problem is augmented if the adjacent channel user is transmitting in a close range compared to the subscriber's receiver. This can also take place if the mobile close to a base station transmits near the channel with a near proximity to the weak mobile.

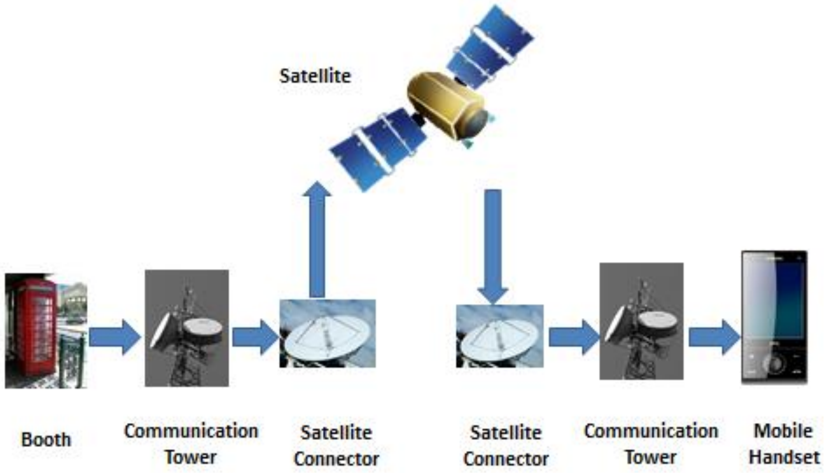

Figure 2.3.1: The process of telecommunication via handsets.

2.4 Radio wave propagation

There are two ways of propagation of electromagnetic signals: through a guided medium or through an unguided medium. Guided medium uses co-axial cables and fibre-optic cables. A signal goes through many propagation effects as reflection, diffraction and scattering. Reflection happens when the wave with a certain wavelength falls on objects that has greater dimensions than the wavelength of the wave. These objects can be earth, buildings and walls. When a radio wave falls on the medium, a part of it is reflected back, while the other is absorbed. Diffraction happens when the wave falls on a sharp object, as the horizon or tall buildings. Every point on the wave front gives rise to the secondary wavelets, and the propagation of these wavelets in the shadowed region gives rise to diffraction. Scattering happens when the medium through which the wave passes has an object with lesser wavelength than the wave. The sound can be heard in a different room having no line of sight.

In a multi-path propagation, the radio wave can reach the receiver in two or more ways. The reasons of multi-path propagation are atmospheric ducting, ionosphere reflection and refraction, and reflection from water bodies and objects as mountains and buildings. The effects of multi-paths include constructive and destructive interference, and phase shifting of the signals. Multi-path interference causes multi-path fading. The effects of fading are: rapid changes in the signal strength, random frequency modulation due to Doppler shifts, time dispersion caused by multi-propagation delays. Factors influencing fading are: Multi-path propagation, speed of the mobile, speed of the surrounding objects, transmission bandwidth of the signal. However, the fading effects are negligible if the signal bandwidth is greater than the channel bandwidth. The vice-versa, that the fading effects are more when the signal bandwidth has a lesser bandwidth than the channel bandwidth.

2.5 Transmission and Reception

The best transmission and reception techniques build on the efficiency of the channel using optimal resources by utilizing bandwidth at low costs. Distortion, noise and interference reduce power and bandwidth efficiency. To counter this, several techniques are used.

Modulation is one of them. Modulation is defined as the process of encoding information suitable for transmission, done by transforming a baseband signal to a passband signal, also known as modulated signal, which is obtained by altering the characteristics of the carrier waves. Demodulation is the reverse of modulation, and is generally done at the receiving end. The characteristics of the modulation are: low bit error rates, low noise to signal ratio, and cost-effectiveness. The efficiency of a modulation scheme is measured by power efficiency and bandwidth efficiency. Power efficiency is obtained when the fidelity of the signal is reserved even at low-power strengths. The advantages of the modulation are to facilitate multiple accesses by allowing multiple users, and increase the range of communication by translating to a higher frequency band, and reduction in antenna size.

Generally there are two types of modulation in terms of linearity: linear and non-linear modulation. The relation between the message signal and the modulated signal determines the type of linearity. A relation is said to be linear if the relation satisfies homogeneity and superposition; where homogeneity mentions that if the input system is scaled by a factor, then the output signal is scaled by the same factor; and superposition happens when the output of the linear system due to simultaneous input systems is equal to the output of the linear systems.

The parameter of the carrier, namely amplitude or angle, determines the classification of angle or amplitude modulation. Amplitude variation involves amplitude modulation, whereas the carrying of sinusoidal waves happens such that the angle of the modulation varies according to the amplitude in angle modulation.

2.6 Multiple Access Techniques

In order to facilitate multiple users within a small bandwidth in an efficient manner multiple access techniques are used.

The most desirable quality of transmission is that the user can talk uniformly to the receiving end from the base station. To increase the capacity of the channel, the following multiple access is used: FDMA or frequency division multiple access, TDMA or time division multiple access, CDMA or code division multiple access, and SDMA or space division multiple access.

IN FDMA, each user is assigned a pair of frequency while making a call through the cellular system. One pair is used for uplink, and another pair for downlink. This is called FDD or frequency division duplexing. Even when the users are not talking to each other, the spectrum cannot be reassigned, as long as the call is in place, which creates a disadvantage. Different users can use the same cell, but they must transmit at different times. FDMA is generally implemented in the narrow band system.

In TDMA technique, continuous transmission is not required as the required users do not use the allotted bandwidth all the time. The entire bandwidth is available all the time but within limited period of time. In TDMA technique, careful time synchronization is used to share the bandwidth. TDMA uses different time slots for transmission and reception, where the number of time slots per frame depends on several factors such as modulation technique, and available bandwidth.

In CDMA, the same bandwidth is used by all the designated users, but all have a different code attached to them. CDMA uses the spreading technique of signals by spreading the narrow band message signal.

In SDMA, the spatial distribution of the users is utilized for a better frequency allocation and an optimal use of frequency spectrum. Earlier, the same frequency was re-used in different cells in a wireless network. SDMA uses spot beam antenna.

2.6 Emerging Technologies

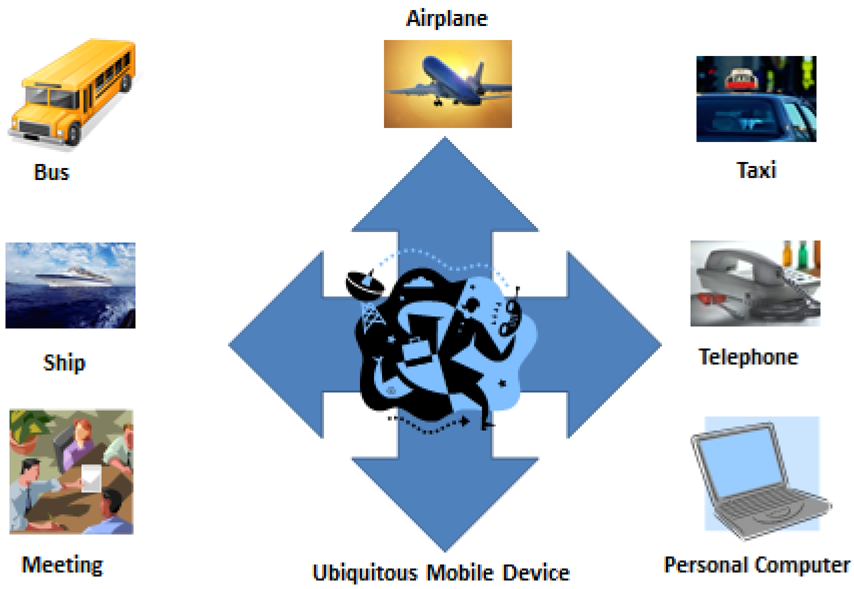

Figure 2.61: The vision of ubiquitous computing

According to Gartner, the top ten mobile technologies that the organizations must master are given below:

1. **Multi-platform Application development tool** – Most of the organizations will build their capacity on the “famous 3X3” or Android, iOS and Windows across native, hybrid and mobile Web.

2. **HTML 5** – In mobile devices, HTML5 is used for mobile devices and applications and it allows development tools, on which applications can be built. However, it is fragmented and undergoing maturity. However, despite many challenges, it will provide a platform for mobile web and hybrid applications.

3. **Advanced Mobile User Experience Design** – Motivational designs, playful interfaces, user designed models, will turn the course of advanced user experience design. Leading consumer applications are pacing on this.

4. **High Precision Location Sensing** – Indoor and outdoor sensing with exact precision on location would be worked out by many companies. This will allow a stronger growth of personalized and ubiquitous applications.

5. **Wearable Devices** – Google glasses have fostered a new path to this discovery. Wearable devices will be the point of adventure for many devices, mainly in sports, fitness, fashion, hobbies and healthcare.

6. **New Wi-Fi Standards** – Over the next half a decade, the need for Wi-Fi infrastructure will increase by leaps and bounds. Emerging Wi-Fi standards as 802.11ac will increase as more organizations will require more applications based on this. This opportunity will enable the new standards and performance level indicators.

7. **Enterprise Mobile Management** – The scope of EMM would require mobile device management, mobile application management, application wrapping, and some elements on synchronization and sharing.

8. **Mobile-Connected Smart Objects** – Around 2025, there would be a greater connection of smarter objects like LED light bulbs, toys, domestic appliances, sports equipment, medical devices, and smart sockets with the mobile in hand.

9. **Long Term Evolution (LTE)** – Long term evolution will improve on the spectral efficiency, and will push cellular networks to peak downlinks. All mobile users will benefit from bandwidth, with better performances on various applications.

10. **Monitoring Tools** – Lastly, the monitoring of mobile devices will allow application performance monitoring or APM, to allow an insight to app behaviour, monitor user behaviour and determine statistics.

2.7 Mobile Middleware

Mobile middleware is a software package that connects other software systems, allowing interoperability. This connection may happen with heterogeneous platforms and varying resource levels. Middleware are expected to be transparent, robust, secure, efficient, and based on open standards. Adaptation is the key to a good middleware system. Mobile agents are an adaptable middleware, which help mobile devices to conserve energy. The framework of service discovery helps to change configurations quickly and easily. The trade-off is generally between the application level and the operating-system-support, and security.

Many mobile users believe that the current hand held devices as PDAs, cellular phones, and portable fax machines, narrows the gap between the mobile device and the traditional mobile device. Mobile applications must strive to make the computing exercises tolerable. To take a case, mobile user is more tolerant of lower quality audio stream than a higher quality audio stream, as the constant pop-ups and breaks do not allow quality streaming due to the bandwidth issues. The question now is, how adaptable should middleware be?

At one part, each application should try to take care of resources and adapt appropriately, while the other part, might allow the applications to be blissfully ignorant of the host operating system, and expects it to be adaptable. Mobile applications are a middle ground of this classical dilemma, and hence the adaptable middleware applications take optimal care of resources, drawing on the need of the user.

Now, what do we understand by the agents? An agent allows programs to move automatically about a network to access resources. In this system, the programs directly move to the servers, gain access to data or computational resource, and practically return to their base server with data. A mobile user can actually allow an agent to disconnect after being dispatched, while connect again to return to the “home-base”. For example a simple search for a word-doc can allow the mobile to create a bibliography while it fetches a tow. A critic might say that this is akin to the client-server structure, but such kind of work include enhancements of building programs in the server side, which makes the administration much more difficult.

The service discovery allows more dynamic interaction between clients and services. This is appropriate for both traditional type of a network, both wired and unwired, as it allows peripheral-poor mobile devices to discover services on demand. With service discovery middleware, developers can quickly develop self-healing systems that can be used for “plug-and-play” at any time.

2.8 Mobile Application Development

Application development for mobile communications are faced with different challenges: limited power, lesser processing speed, varying levels of connectivity, disconnected operations and discovery of the required services. Mobile applications work under certain constraints, namely, less power, volatile and non-volatile memory, network bandwidth, while maintaining screen resolution. Given a certain constraint on available bandwidth, a mobile device might stop working with high bit-rate, and use a lower quality stream.

The adaptation strategy requires fidelity, agility and concurrency. Fidelity means the data item available to an application, which includes perceived quality and consistency. Let us say that, a server might store a 60-frame-per-second, 24-bit colour depth, at 1600X1200 resolution which is 100% fidel. Now, owing to constraints as limited network bandwidth, a mobile host will play at lower bit-per-second which will be of lesser fidelity. Adaptation provides the higher fidelity, while projecting resource levels. Now, agility measures a middleware’s responsiveness to changes in resource levels. An agile system will quickly determine how the network bandwidth has changed, or if any battery replacement needs to be done. If the middle ware is very slow to large increase in network bandwidth, then the probability to perform opportunistic caching may be lost, where a large number of data may be collected due to the higher bandwidth. Agility implies both speed and accuracy. If at higher bandwidth, a video is streaming, then for shift of bandwidth to a lower level, some of the frames are dropped. The last measure for bandwidth is concurrency, which means that even the least powerful mobile device, will allow concurrent applications to be run at the same time, while competing for bandwidth and power. For the mobile device to be intelligent, each application would need to be aware of resource requirements of other applications, and monitor available resources.

Now, when multiple applications want to adapt to limited resources; conflicting adaptation, suboptimal system operation, and suboptimal user experience takes place. Let us assume that a number of applications executing on a mobile host wants to write data to a disk, and each time one of the back-up facilities execute, a hard disk on the system comes into the picture. Now, if various applications perform automatic back-ups at non-synchronous times, then the disk will move more to perform automatic backups. If however, the co-ordination takes place, then the disk can write in numbers, so that the disk remains being non-active or not powered. Conflicting adaptation happens when an application is adapting to various networks and bandwidths. In that case, the battery level becomes a concern, while the power conscious application will use the network and its interface. This allows more bandwidth which will raise the fidelity levels for a data stream. Also, the limited resources might pose a big problem as a person will have to lower the fidelity level of a downloaded streaming video when the available bandwidth decreases sharply.

Another type of mobile middleware is mobile agents. All the computer users have mobile code, and that code travels from one server to another in search of information. Mobile agents move freely about a network, taking their own paths to the servers. In case a mobile user needs to search a database, a traditional approach is procedure call against the database server. A mobile application would dispatch one or more applications close to the server on another case. The agent then reaches the server, performs queries, and then reaches to the client or server. The advantages of using a mobile agent are that a myriad of applications can be supported by mobile agent system, e-commerce, network system, and information retrieval. The mobile agent has the following advantages: limitations of a single client are reduced, greater customization and adaptable connection in terms of flexible operation is achieved. However, the concern is that mobile systems lack standardization inter-operability. Also, security is a concern. For this, a mobile agent must be prevented from doing any sort of damage while it transmits through the network. Also, the agents must be protected from any damage.

The migration of the agents happens when it is possible to capture the state of an agent, or use additional resources to capture the state of the agent. This process is carried along the remote machine, to which the agent will migrate. This is akin to checking, where the stack, heap, program code, static variables is captured and reused. In fact, the virtual machine can be check pointed, but the issues like portability is not addressed, and hence network connections and file access will still pose an issue. A good solution is to use a strong restriction to the programming model used for mobile agents. This explains sufficient information about the current execution, combined with the local clean-up. This implies that an agent can simply tear down communication connections, while closing local files, before allowing the middleware perform a migration operation.

Communication among agents in a mobile system can take many paths, mainly remote procedure calls, remote method invocation, co-ordination languages, mailboxes and meeting places. To consider this, we need to know about temporal and spatial locality. Temporal locality means that communication among two or more agents must take place at the same time. Transit agents will fail in this communication. While spatial location means that the participants must name each other for communication, which is complete to know the agents location.

2.9 Service Oriented Middleware

Mobility introduces an interesting challenge as mobiles are less resourceful than their plugged-in counter-parts like desktops, PCs. The help of service discovery allows mobiles to be resourceful. Service discovery frameworks, hence, make networked services less tiresome to deploy and configure. As an example a fax machine becomes usable as soon as it is plugged in. Service discovery enabled clients can find the fax machine at once, without allowing the fax machine to be discovered by the user. If the mobile client is going to the next floor of the office, then the discovery of the next fax machine happens automatically. These types of services are propped by service discovery technologies. A service discovery key-chain can be used for practical purposes to turn on lights, transfer desktop settings, or adjust stereo systems as the user becomes mobile. A service discovery framework is a collection of protocols that develop highly dynamic client-server applications. But there are several questions to be answered about the types of services, the type of client contact services, protocols used, fault tolerance and so on.

The most basic interactions between clients and services are service discovery and advertisement. Now, service advertisement allows the discovery of services, while the services enter the network, and departure is notified when the service leaves the network. In service discovery, the clients automatically discover the services in the local network. This discovery attempts to find the services needed, including standardized service name types, and service characteristics. Now, whenever the services are sought directly, a client automatically generates little configuration. The frameworks for service discovery standardize the operation of service catalogues, garbage collection facilities, security and the development of protocol.

The common grounds for service discovery are:

1. **Standardization of Services** – Service types should be standardized, to support the discovery of services. In standardization, the meaning of standardization is taken into account. It defines operations supported by the services, the protocols maintained, and attributes that provide extra information about the services.

2. **Discovery of Services** – The necessary services may be discovered with less knowledge about the network. Clients can look for service type or defined attributes. More eloquent services can sharpen their discovery requests more carefully.

3. **Service "subtyping"** – Now, the client may be requested to a specific service type, like a high-resolution 3D image printing. Service subtyping allows only a bare minimum service type to carry standardization, while more specific instances need to inherit or expand on this issue.

4. **Service insertion and advertisement** – This allows the non-static insertion and removal of services from a network, providing the extension of the dynamic "plug and play" operations. With minimum configuration and advertisement, the services are leaving the network.

5. **Service browsing** – Browsing allows clients to explore available services, without any prior information of the network. This is akin to "window shopping", where the user has a free hand to choose whatever he wishes for.

6. **Service catalogue** – Some support catalogues maintain listings of available services. When the services catalogues are used, they provide ads to one or more catalogue, rather than interacting with the clients instantly. This allows greater flexibility in allowing services in the local network, and reduction in traffic.

7. **Eventing** – An eventing mechanism allows non-synchronous information of interesting conditions. It allows polling and hence reduces the burden on network.

8. **Garbage collection** – The garbage collection allows the unusable and non-important information out of the network. Without this process, the performance could suffer, as clients contact non-existent services or the services continue to perform operations.

9. **Scoping** – Scoping controls service discovery and service advertisements. It has two ways: the first controls the multicast communications, while the second actually associates the name with services within the service groups.

2.10 1G, 2G, 3G & 4G

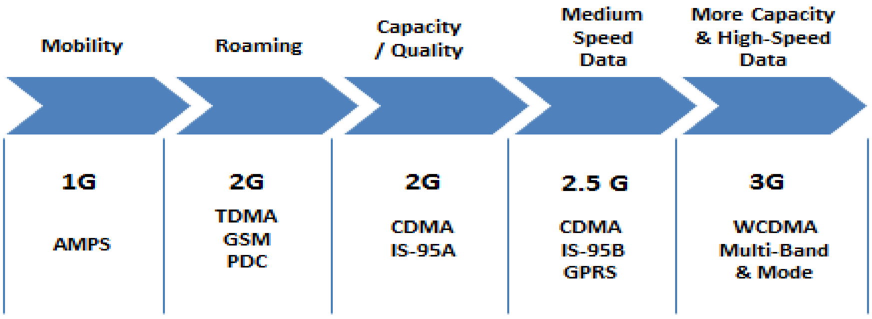

Figure 1.1- Evolution of the technology in mobile wireless.

The First Generation or 1G network was based on analogue or continuous signals. In the USA, they were known as Analogue Mobile Phone Systems (AMPS), while the rest of the world knew it as a variation of Total Access Communication Systems (TACS). The devices were manufactured on the use of voice only, and not data. There was no possibility of roaming or efficient use of spectrum. The main difference in 1G and 2G network is that 2G had digital networks. Using 1G, a voice call got modulated at a higher frequency range of 150 MHz for transmission between the towers. The disadvantages of 1G were low capacity, unreliable handoff, poor links in voice, without any security making vulnerable for the access of the voice.

The Second Generation networks or 2G networks started in the late 1980s. Primarily, they were used for voice transmission over digital signals, with a speed upto 64 kbps. This network facilitated SMS. In the early 1990s, 2G phones using GSM Technology were used. The use of GSM modulation improved the voice quality, but the data service had limited offers. Eventually, the 2G services also offered additional services, such as paging, faxes, text messages, and voicemail. The limited data services included WAP, HSCSD, and MLS. An intermediate phase was 2.5G network in the late 1990s. It used the GPRS Standards, which delivered packet-switching technique for delivering data. This increased the rate of rise of internet protocol or IP.

3G or the third-generation network is based on wide band wireless network. It provides a peak data of at least 200Kbits/ sec. In India it is generally in the range of 2100 MHz, with a band width of 15-20 MHz. 3G promised internet access. The service providers for mobile used the licensed spectrum to give wireless coverage. The key feature of this service is that it allows ubiquitous and continuous service to the mobile devices, even when the customer is driving at a high speed along the road.

4G is the next generation network for cell phones or hand held devices. Currently, India is on a transition phase from 2G to 3G.The table for comparison between 1G, 2G, 3G and 4G is as follows.

Property	1G	2G	2.5G	3G	4G
Starting Point	*1970-1984*	*1980-1991*	*1985-1999*	*1990-2002*	*2000-2006*
Technology	*Analogue Signal*	*Digital Signal*	*Digital Signal*	*Broad Bandwidth*	*Unified IP and a seamless configuration*
Standard	*AMPS, TACS, NMT*	*GSM, TDMA, DMA*	*GPRS, I-MODE, HSCSD, EDGE*	*WCDMA, CDMA-2000*	*Single unified standard*
Bandwidth	*1.9 kbps*	*14.4 kbps*	*14.4 kbps*	*2 mbps*	*200 mbps*
Multi-Address Technique	*FDMA*	*TDMA, CDMA*	*TDMA, CDMA*	*CDMA*	*CDMA*
Core Network	*PSTN*	*PSTN*	*PSTN and Packet network*	*Packet Network*	*Internet*
Switching	*Circuit*	*Circuit*	*Circuit for access network*	*Packet except circuit*	*All Packet*
Service Type	*Voice mono-service*	*Voice, SMS*	*Higher Capacity, Packetized data*	*High Quality, Audio, Video, Data*	*Dynamic Information Access*

Table 2.10.1: Comparison of wireless technology generations

Clearly, as the networks evolve towards 4G, more speed of the network and high-capacity of the network for data transmission is used. With the advent of 4G, there has been a considerable research on long term evolution as well.

2.11 LTE & The Future ahead

The main objective of 4G network system is to utilize the bandwidth given. To meet the standards then, the requirements of IMT-Advanced and as well as 3G operators, LTE-

Advanced can use the bandwidth till 100 MHz, in several frequency bands. By supporting several frequency bands, the flexibility of LTE-Advanced also increases; but this allows fragmentation in which several countries use several frequency bands for their users. LTE-Advanced uses this opportunity as much as it can, to introduce the flexibility of use of multiple frequency bands through the use of carrier aggregation. Carrier aggregation consists of component carriers, to achieve wider transmission bandwidth. An LTE-Advanced device can aggregate up to five component carriers, each of up to 20 MHz; and to support the LTE devices, component carriers are configured as a typical LTE Carrier.

LTE-Advanced not only supports a wider bandwidths, carrier aggregation also supports inter-cell interference mitigation, handover improvement, energy-savings and load balancing. Carrier aggregation, albeit has some issues like the design of high-performing transceiver architectures, managing available carriers to provide enhanced service, and introduction of new carrier types.

The ways with which we can use an efficient network consists of the following ways: new carrier types, resource management, multi-stream aggregation, network sharing, wideband transceiver, carrier aggregation enhancements, and new frequency bands.

In new carrier types, the legacy control signalling, and cell-specific control signals, will be reduced to tackle the carriers. In legacy carriers, cell-specific cells are always relayed, being independent of the actual load in the cell. Hence, the base station uses up energy and causes interference even in the absence of any load. The first sub-frame of each sub-frame consists of resources, which are specific to them, and is used for legacy control channels. These specific resources are used for data in the absence of legacy control channels. High-density heterogeneous networks use this type of a system to benefit.

By introducing carrier aggregation, the network enables the use of a subset of component carriers with the enhanced nodes in the network. This decision would be based on different objectives like improving the robust nature of mobility procedures, coverage capacity, load balancing, reducing energy consumption, and as well as inter-cell interference. The fundamental scope of carrier aggregation is to enable a single node to serve its users to utilize two or more component carriers. With time, cellular networks have become heterogeneous, where several small cells are deployed under the coverage area of bigger cells, with the hope that an LTE-Advanced device will be capable of aggregating component carriers belonging to the small and macro cells. But, this scheme needs to avoid inter-cell interference. Also, the carrier aggregation needs to be supported not only in LTE and LTE-Advanced, but also to base stations belonging to other technologies as well. It allows significant improvement in the network, especially if there is an existence of imbalance of the utilization of the radio access techniques.

In network sharing, multiple networks not only share equipment, but also radio frequencies that each one owns. But this works on per-site basis. The natural way of advancement is to allow carrier aggregators allowing sharing to the component carriers in order to have cross-operator multi-stream carrier aggregators. The first benefit of this process allows the users to have an access to higher bandwidths; and hence high-capacity and coverage. The next advantage is allowing intra-band carrier aggregators in scenarios which were not possible before. If an operator has an access to more than one component carriers at a time, belonging to two different spectrum bands, this process will support inter-band carrier aggregators.

In wideband transceivers, the architecture must be designed in such a way that it balances cost, energy consumption, and performance. On one extreme lies the option of processing all frequency bands, by using a single radio frequency chain. On the other side lies the option of using a separate radio frequency chain for each frequency band. The first option is simpler and has a lower cost than, including less power consumption, but it can support only contiguous carrier aggregator. However, the second option can be used in intra-band as well as in inter-band carrier aggregators. To do so, at the base station future modifications to the standard software defined radios will be utilized. This will provide a harder platform which can be changed by software updates.

In carrier aggregation enhancements, the modifications are used to support aggregators, were done at the MAC layer, and hence the procedure are still executed on a per component carrier. This allows a sub-optimal performance as compared to a configuration where the procedures are done jointly across all the component carriers. As an instance, the use of carrier aggregators increases the peak-to-average power ratios, which has a good effect on the efficiency.

In new frequency bands, the carrier aggregators depend on the availability of more spectrums that can be put together. The two approaches to possibly acquire such a spectrum are exclusive access and shared access. The exclusive access entails the sole use of particular spectrum bands, while the shared access allows an operator to utilize spectrum that has been licensed to another incumbent user, but underutilized in certain areas and times. As an instance, in the USA 3.5 GHz is used for naval radar, which is expected to be heavily used in coastal areas, and not in other areas. However, the Coast Guard can establish an agreement with other operators by allowing them to use 3.5 GHz for non-coastal areas. This would allow operators to have access to highly-desired frequency bands without requiring incumbent users vacating their spectrum bands.

There is another technique called Multiple Input - Multiple Output (MIMO) that is an essential technology for every current and future wireless system trying for higher data rates. Different approaches can be formed, namely spatial diversity, spatial multiplexing, beamforming, and spatial division multiple access.

Multiple antennas can be utilized to improve the quality of transmission. Multiple antennas transmit pre-coded versions of the same data stream, while the multiple antennas at the receiver end may use several combination of different type of signals. This is spatial diversity. In spatial multiplexing, the user can increase several data streams and which requires pre-coding at the transmitter to orthogonalize the streams. It requires specific reference signals that allow the utilization of pre-coded weights that are not restricted to a code book, as reference signals are pre-coded with the data. In beamforming, a group of antennas can be used to reach the users at end of coverage area. In spatial division multiplier access, several users can be co-scheduled on the same frequency and time resources. However, this technique does not have enough flexibility to cancel intra-cell interference.

In the next generation wireless network, multiple input-multiple output (MIMO) will play an active part. Let us try to understand the use of massive MIMO, 3D Channel modelling, feedback enhancements, reference signals, and codebook design issues. In massive MIMO, systems make use of antenna arrays, with a large number of antenna elements. This number of larger arrays can accommodate a large number of users, improve on interference, and greatly improve on the interference of the cell user's performance and coverage. It allows the reduction of the transmission power, and achieves better performance under the same regulatory power constraints. However, there are certain challenges as well. The pilot contaminated problem has been assessed as the ultimate power limiting factor in the massive MIMO system. This interference effect appears in multi-cell scenarios with non-orthogonal pilots in different cells, as channel estimates for a given cell will be disturbed by pilots transmitted to the other cells. When the number of antennas increases without any limit, uncorrelated noise and fast fading vanish, and this can cause the pilot contamination as the main problem.

When the incident power is rich in the elevation domain, or the antenna arrays are also vertically distributed, the former assumption that the channel path consists of 2D plane does not hold. In 3D channel modelling, the layout of the antennas is capable of forming beams in the vertical domain. Hence, there is a need for accurate and reliable 3D channel models that requires both the azimuth and elevation directions in a signal propagation path from a base station to a user. Yet, the multipath fading characteristics in both azimuth and elevation dimensions must be correlated to a large scale fading parameters.

In feedback enhancements, reference signal and code book design; further optimizations are used to achieve the designs of all these three elements. As an instance, better trade-off solutions are needed for the feedback accuracy versus the incurred overhead needs to be found. Finer spatial-domain, as well as frequency domain feedback granularities are required to support different antenna polarizations and configurations. Optimized feedback solutions for heterogeneous networks and uplink feedback channel enhancements will be a part of future research.

2.12 Case Study: Online and Mobile Banking in China

The year was 1997. It was observed by authors (year) or (Author, year) that China Merchant's Bank launched the internet payment system in China, and then the internet banking and the telephone banking started to spread in Mainland China.

Although the use of internet is low, and electronic banking is still very less, the advantage of being convenient, safe, efficient and economical; Chinese domestic banks are confident that electronic banking benefits would outgrow traditional banking services in the future. Were they correct in estimating this?

Most retail banks in China provide online banking services to the existing bank activities, while mobile banking has just taken off. In order to proceed further, the largest mobile banking operator in China joined hands with three banks- Bank of China, Industrial and Commercial Bank of China, and China Merchant's Bank, to implement this new service which has many good advantages- guarantee of safety of the client funds, 24/7 access, a cost effective rate of 0.1 Yuan, for every successful transaction, and no charge for any non-successful transactions. Now, would there be a sea-change for the online and mobile transactions?

Since 1998, China witnessed a high growth of information technology developments, including internet access. Albeit the distribution is low for personal computers, with 2.5 percentages of people owing a personal computer in the household, the rapid growth ensured that China would become the largest mobile market by 2010. Now, AC Neilson Consult China found the population of emergent internet bankers was growing at a rapid pace of 56%. Yet there was a stigma to this growing opportunity- lack of influence from the market place, and government restrictions to limit the ability of the private firms to contribute to the internet infrastructure. As an instance, there were too few businesses and consumers holding credit cards. Adding to this were many obstacles in China like non-acceptance towards a new technology driven banking services, life-style of local people, attitude towards the credit cards, traditional concept and habits of personal financial management and low penetration of the internet for online and mobile payment. Now, will the online and mobile payments take off?

As far as mobile banking was concerned, it was still in the development phase in the USA and Europe, where a small market with a few users were reported. This was due to customer acceptance and slow service.

Research on consumer attitude and adoption of electronic banking showed that there were several factors that stated the consumer's attitude towards the online and mobile banking systems, such as person's demographic, motivation and behaviour towards different banking technologies. Added to this was the prior knowledge of computers and new technology. The demographic factors revealed that the younger consumers value the convenience or time more than the older customers. It was further established that the educational levels did not hamper the acceptance rate of this new technology. Now, will this affect the acceptance rate of the mobile banking of the customers?

In the case of mobile banking, and traditional retail branches, the customers would adopt new-technology driven delivery channels. Research showed that consumers are not generally pre-determined to change their behaviour radically and adopt widespread usage of online banking. Infact, the past research showed that the consumers switched delivery channels from the traditional to the new technology mainly because of dis-satisfaction of the current banking facilities, including influences from the family members. This might be slow speed of service at the bank, inconvenient branch opening hours, and a small number of branch staff available to the branch customers. It is also said that the delivery of the specified services helped the correlation of high-satisfaction. Research also proved that a degree of trust was always correlated with perceived risk and commitment.

In order to understand the nature of acceptability of adoption of mobile payments in China, it is important that the culture of China needs to be appreciated. Chinese customers tend to have a greater uncertainty avoidance which requires a greater need for strict regulation and legislation to ensure limited uncertainties. Lack of proper regulation is a barrier hindering mobile transactions, as the Chinese customers are more concerned with security. Also, the Chinese customers have a weak time perspective. Hence, they prefer familiar branch banking services. However, there are some consumers who adopt the new technology quite quickly. Even the consumers can be segregated into five categories: innovators, early adopters, early majority, late majority and laggards.

Conclusively, we can say that the mobile and online banking are still at a nascent stage in China. The current target market is relatively small for the awareness factor, but there is a good potential in the corner. The habit of Chinese consumers was also an obstacle to the growth of mobile banking adoption. In contrast to the Western Countries, Chinese adopters were predominantly male persons, not typically young neither highly educated. Users were widely spread among the salaried employees, senior managers and small business owners. To raise awareness, women can be targeted for adoption of the new technology. Advertising messages can emphasize security for online banking and novelty for mobile banking.

Questions

1. What could be the differentiating factors for early adoption of mobile banking in China?
2. Why did initially China fail to have an adoption towards this new technology?
3. What are the potential risks associated with the mobile banking adoption?

4. How does China stand vis-à-vis the Western counterparts in mobile and online payment adoption?

2.12 References

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