UNIT 1 INTRODUCTION TO MOBILE COMMUNICATIONS

1.0 INTRODUCTION

If we have to predict the transition of computers in the next decade based on the transition in the last two decades, our imagination will probably run out.

Mobile communication has known no bounds in becoming more efficient both in terms of time and money. Earlier there was no mobility in communication. If suppose a person had to make a call, he/she was stuck by the side of a wired device to do so. Today we can make a call through a smartwatch or even a voice command. By this premise, it is unimaginable how flexible communication will get in the coming decade.

In this Unit1, we will look upon the different advances in communication over the years. Even though a lot of techniques get outdated, their basis are often used to make enhanced devices for communication.

A communication device often shows one of the following features:

Fixed and wired: For example a desktop PC. It is not applicable for mobile usage due to its weight and power consumption.

Mobile and wired: For example, a laptop can be carried from one place to another and can connect to any network.

Fixed and wireless: For example, installing networks, like those in historical buildings. It is done to avoid any damage that might be caused by installing wires.

Mobile and wireless: For example, GSM, which has no cable restrictions and can travel between different wireless networks.

1.1 OBJECTIVES

At the end of this Unit, you shall be able to:

(i) understand the concepts of Mobile Computing, how it works and the various features of Mobile Computing.

(ii) Understand multiplexing concepts, its different type, its advantages, disadvantages and applications.
(iii) Understand how GSM works and its advantages and disadvantages.
(iv) Understand how GPRS works and what are its features.
(v) Understand how 3G works and learning its advantages and disadvantages.
(vi) Understand how 4G works and learning its advantages and disadvantages.
(vii) Understand the difference between LTE and WIMAX.

1.2 MOBILE COMPUTING

Mobile Communication refers to the infrastructure put in place to facilitate and support the stated services with regard to seamless and reliable communication. Devices such as protocols, services, bandwidth, and portals are part of this infrastructure. At this stage, the format of the data is defined. By doing so, a collision with another system offering the same service is avoided.

Essentially, the overlaying infrastructure is radio wave-oriented since the media is unguided/unbounded. Therefore, the signals are transmitted over the air to devices that can receive and send the same types of signals.

1.2.1 User Mobility

An individual who has access to the same or similar telecommunications services at different locations is referred to as a mobile user. The user can move between different geographical

locations, networks, communication devices and different applications.

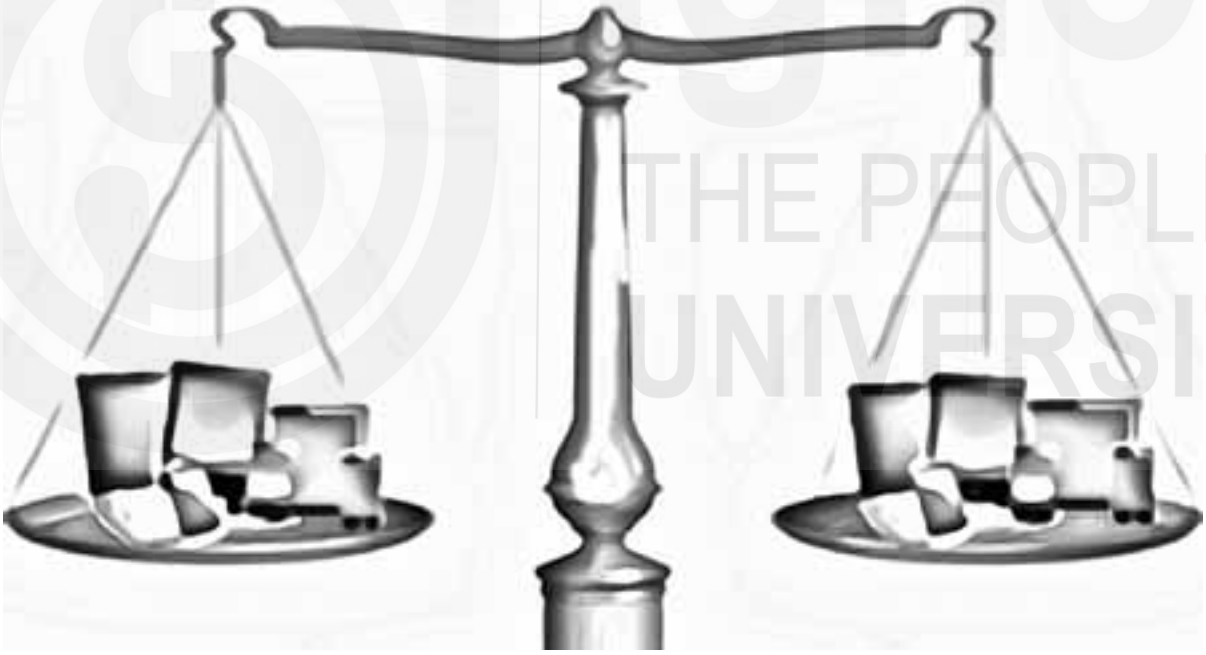
1.2.2 Device Mobility

A number of mechanisms are present in both the device and the network that ensure that communication is still possible even while the device is moving. The device moves between different geographical locations and networks.

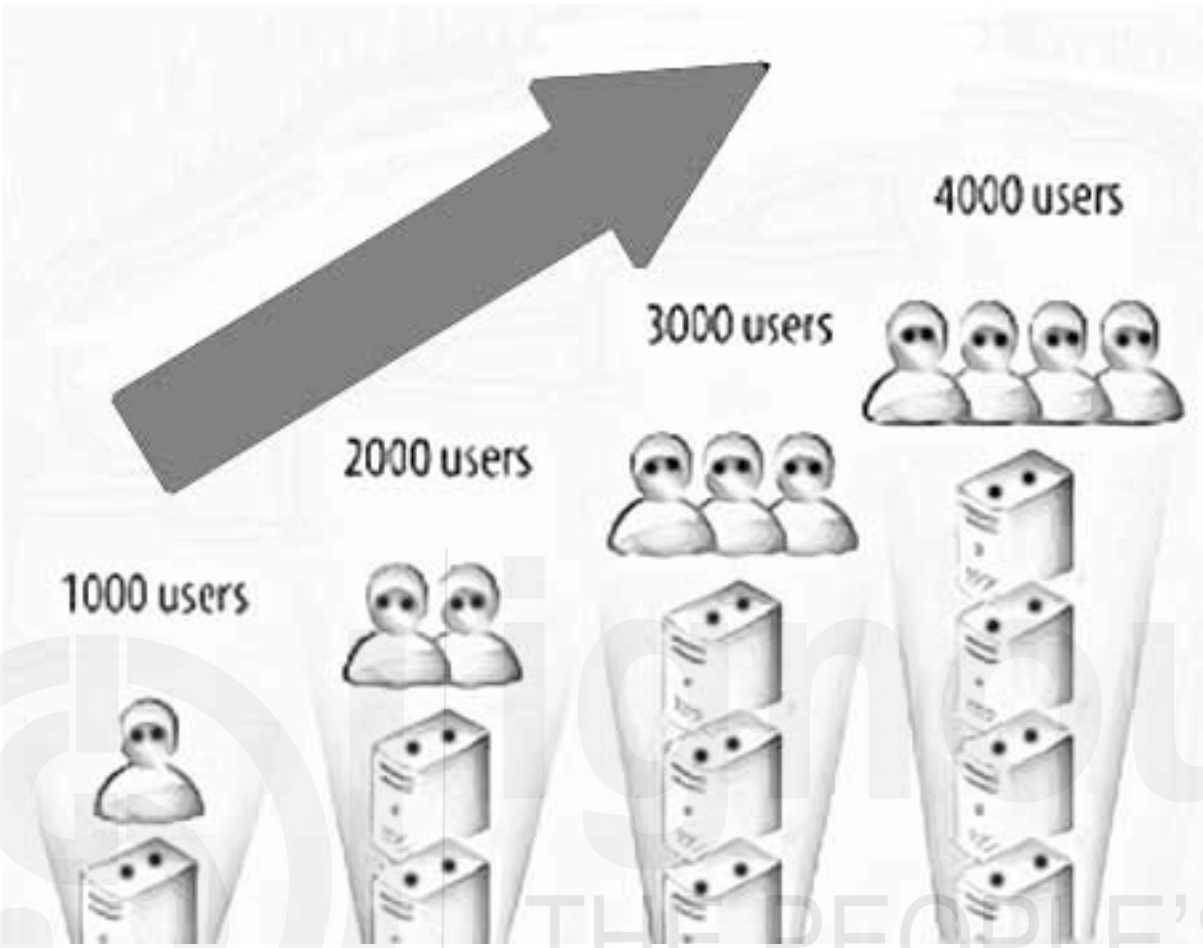
1.3 FEATURES OF MOBILE COMMUNICATION

A high capacity load balancer is essential for all wired and wireless infrastructures.

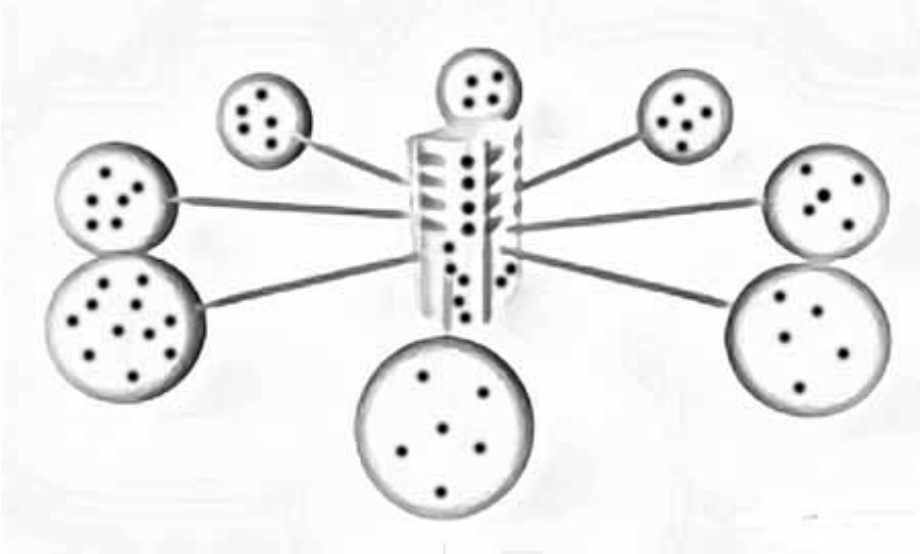
When one access point is overloaded, the system will automatically choose a different access point based on the available capacity.



1.3.1 Scalability: Wireless devices continue to grow in popularity every day. As long as coverage and capacity are not overextended, the wireless networks can expand as requirements change - without having to rework or re-create the entire network.



1.3.2 Network management system: There are now a great many different components in wireless networks, such as access points, firewalls, switches, and managed power. Wireless networks offer a better way to manage the entire network.



1.3.3 Role based access control: Using role-based access control (RBAC), you are able to assign roles based on what, who, where, when and how a user or device is trying to access your network. Access control rules or policies can then be enforced based on the ends or roles of the device.

1.3.4 Provide outdoor and indoor coverage options: Your wireless system should provide outdoor and indoor coverage. It is important that a secure registration process be used for network access control, also known as mobile device registration.

In addition to controlling the role of each user and enforcing policies, network access control can be configured to allow users to register themselves with your network.

1.3.5 Manage mobile devices: Imagine a scenario in which thousands of mobile devices access your wireless network and run thousands of applications.

1.3.5.1 Roaming: As you move throughout your office or even from one building to another, you won't experience dropped connections, slower speeds or any interruptions in service.

1.3.5.2 Redundancy: Depending on your specific needs and environment, your wireless system may require varying levels of redundancy.

In order to maintain proper security, you must use the right firewall. Your network firewall is the system's backbone. Having the right firewall in place will help you in many ways:

(a) Apps and users can be viewed and controlled.
(b) Reduce complexity by Antivirus protection. Deep Packet Inspection (DPI) Filtering applications.
(c) Ensure your network and users are protected against known and unknown threads including: zero-day, encrypted malware, ransomware, malicious botnets.

1.4 WHAT IS MULTIPLEXING?

As a technique in electronics and signal processing, multiplexing is a method of combining multiple analog or digital signals into one over a shared medium. In mobile computing, communications, and computer networks, multiplexing can be used to combine analog or digital signals.

The means of communication can include radio frequency (radio) and cable (cable). All media can be multiplexed.

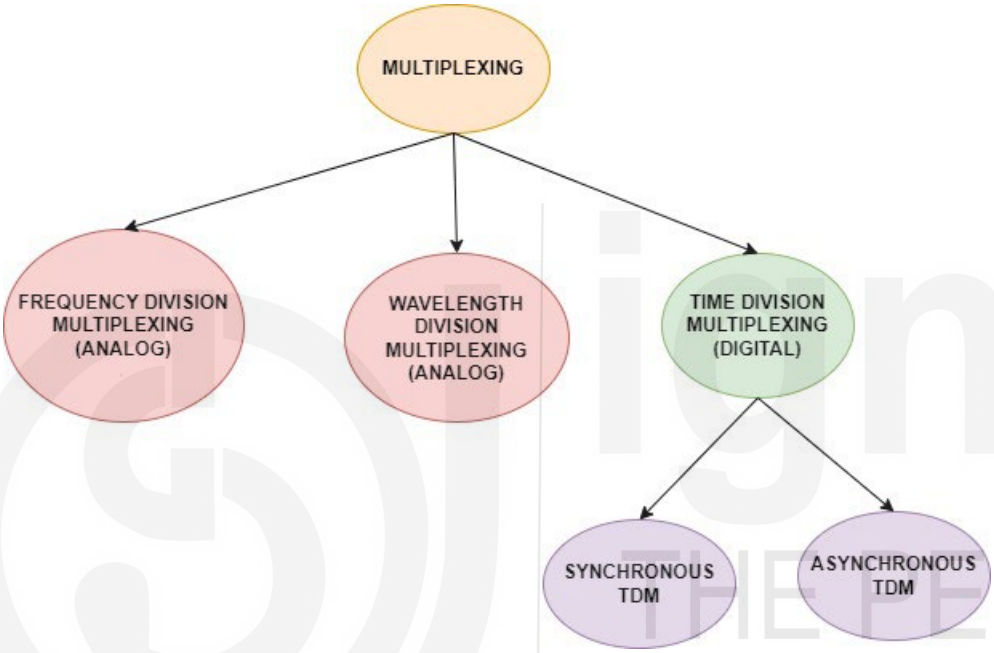
An example of multiplexing is how multiple calls can be connected through one telephone wire.

Types of Multiplexing

1. Frequency Division Multiplexing (FDM)

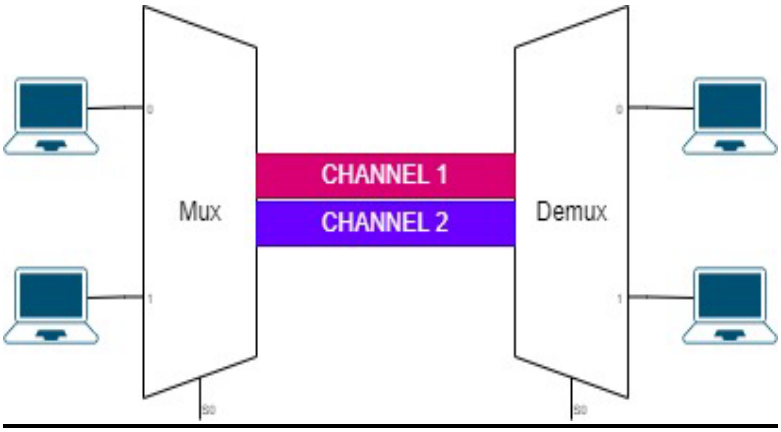
2. Time Division Multiplexing(TDM)

3. Code Division Multiplexing(CDM)



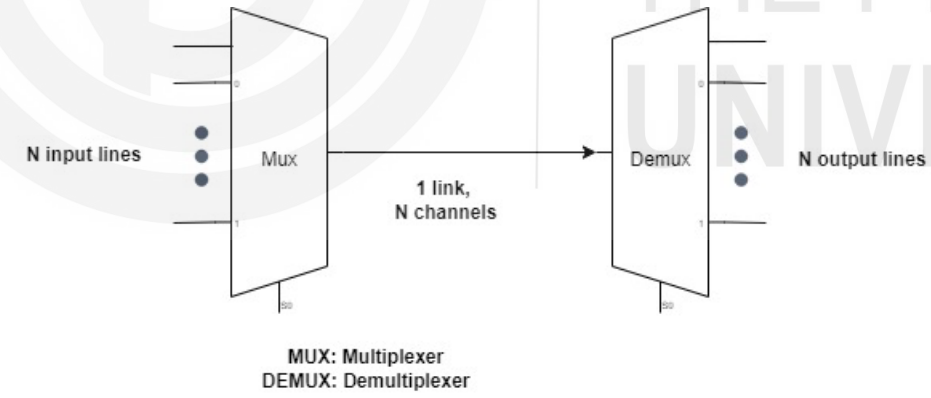
1.4.1 Frequency Division Multiplexing (FDM)

There are several signals being transmitted simultaneously, and each source transmits its signals within the allotted frequency range. The two adjacent signals are separated by a suitable frequency gap to avoid overlapping. Due to the signals being transmitted at the allotted frequencies, the chances of collisions are decreased. Several logical channels exist in the frequency spectrum, each of which corresponds to a particular bandwidth. Several signals are sent simultaneously at the same time, each with a different frequency band or channel. Such transmissions are used in radio and television. Guard bands are therefore used to avoid interference between successive channels.



1.4.1.1 Advantages of FDM:

1. Easy to implement.
2. Efficient even when traffic is constant.
3. No equalization required.
4. It can be possible to increase capacity by reducing the knowledge bit rate and using efficient digital codes.
5. It is not difficult to implement technological advances. For instance, systems are often designed so that improvement in terms of speech coders can be incorporated easily.
6. Since FDMA systems use low bit rates (large symbol time) in comparison to average delay spread, they are less expensive and exhibit low Inter Symbol Interference (ISI).



1.4.1.2 Disadvantages of FDM:

1. Guard Bands, although necessary, can also be seen as a wastage of capacity.
2. Network planning is time critical.
3. Low capacity of traffic.
4. Requires expensive multi-channel receivers.
5. The system may be more expensive if RF (Radio Frequency) filters must meet stringent specifications for adjacent channel rejection.

6. Due to the fact that channels are assigned for a single user, there are idle channels in a general system.

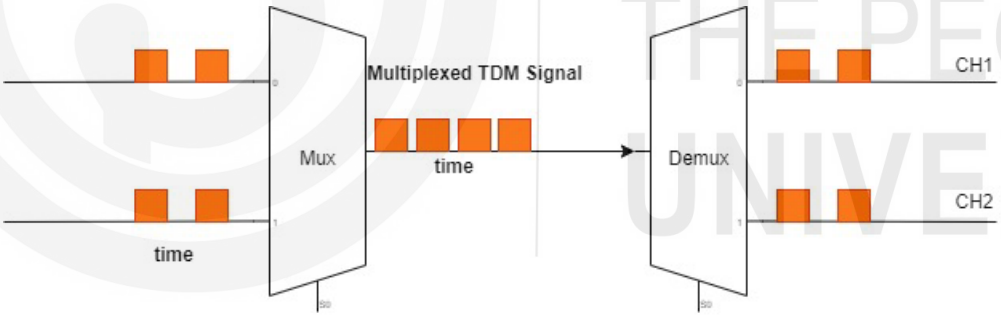
1.4.1.3 Applications of FDM:

FDM is used in:

1. Telephone system.
2. FM & AM Radio broadcasting.
3. Cable TV.
4. Walkie talkies.
5. Mobile network for a closed user group. e.g. Wi-Fi.
6. Total access communication systems (TACS)
7. 2G mobile communication.

1.4.2 Time Division Multiplexing(TDM)

Time Division Multiplexing (TDM) is a multiplexing technique that enables multiple data signals to be carried in different time slots over a common communication channel.
One frame is said to be transmitted when its entire signal gets transmitted across the channel. Time slots are used to divide the overall time domain into multiple fixed length time slots.



MUX: Multiplexer
DEMUX: Demultiplexer

1.4.2.1 Synchronous TDM

In Synchronous TDM, each time slot is pre-assigned to a constant source.
It is based on the assumption that data will be present at the source regardless of how the slots are allocated in advance. This results in wastage of channel capacity since time slots are completely wasted in the absence of data.

1.4.2.2 Asynchronous TDM

Asynchronous TDM, also known as statistical division multiplexing, is a method in which time slots are allocated only to machines that have the required information to send data.

1.4.2.3 Advantages of TDM:

1. TDM is very flexible.
2. The circuitry is not as complex,
3. Cross talk problem is not so severe.
4. The channel bandwidth can be completely utilised for each channel.

1.4.2.4 Disadvantages of TDM:

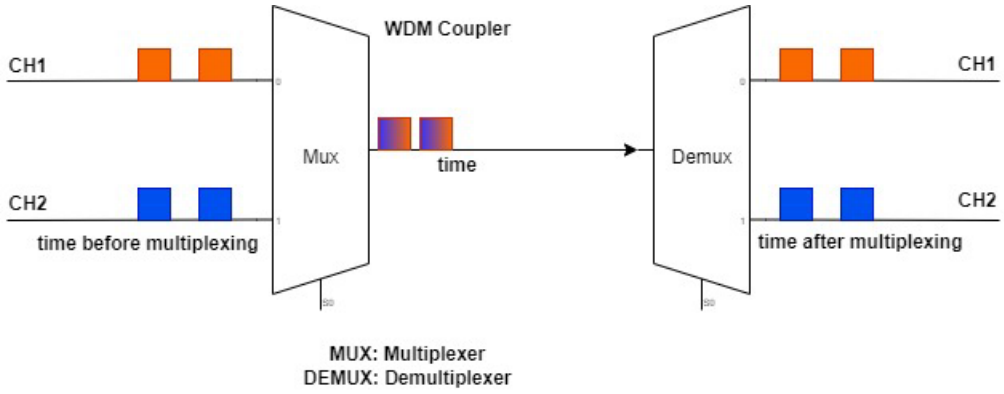
1. Synchronization is required.
2. The implementation is complex.
3. Slow narrowband fading may wipe out all TDM channels.

1.4.2.5 Applications of TDM:

1. It is used in SONET (Synchronous Optical Networking).
2. It is deployed in a public switched telephone network.
3. It's found in telephone wired lines.
4. It is used in digital audio mixing systems.
5. It is used in a half duplex communication system.
6. It is used in GSM.

1.4.3 Wavelength Division Multiplexing

Wavelength Division Multiplexing (WDM) is a networking technique that allows multiple data signals to be simultaneously transmitted over a common frequency band.
The technology of WDM is used when multiple users are permitted to share one communication channel.
As multiple users transmit within the same frequency spectrum, WDM provides some level of security. To decode each transmission, the spreading code must be used.



1.4.3.1 Advantages of WDM:

1. The WDM channel is not effectively decodable, thus it provides enhanced protection for cell communication.
2. Due to the greater number of clients per MHz of data transmission, it has multiple times the limit of GSM so it provides better inclusion and requires fewer reception devices. It also burns-through less force to expand client limits.
3. The voice quality is just as good as the sign quality.
4. There is flexibility in the asset designation.
5. It is incredibly efficient.
6. There is no need for synchronization with WDM.
7. It can transmit data to a large number of clients simultaneously.

1.4.3.2 Disadvantages of WDM:

1. It requires time synchronization.
2. As the number of clients increases, WDM framework execution degrades.
3. As a WDM user, choosing the code length can be a laborious process, since it can cause delays.
4. The quality of administration diminishes when the amount of clients expands.
5. When we use WDM strategies, we encounter the close-far issue, Self-sticking issue.

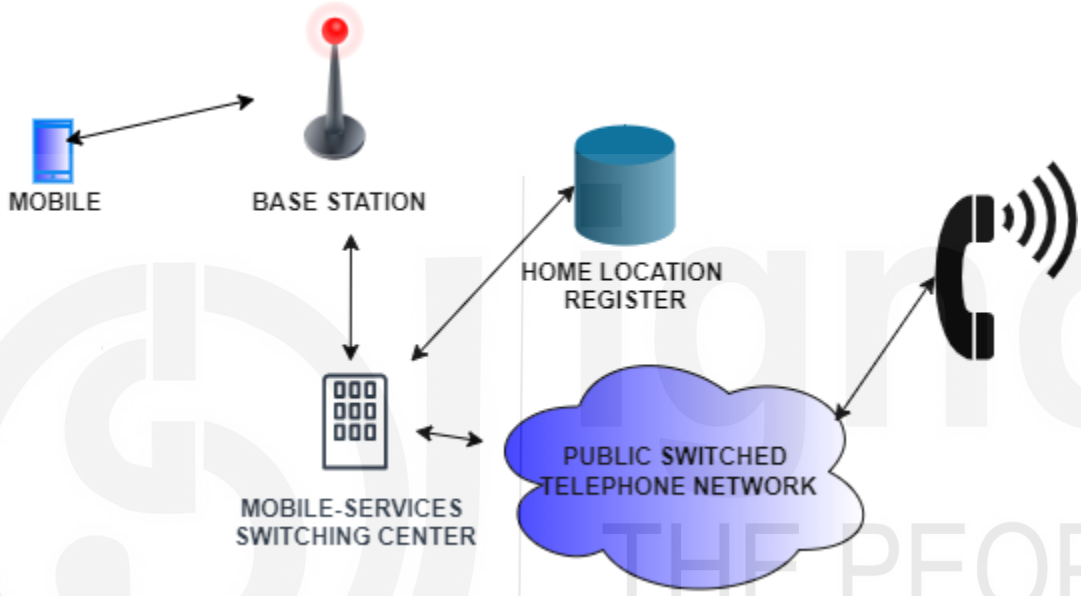
1.4.3.3 Applications of WDM:

1. It is used for military and commercial applications.
2. It is implemented in mobile communications.
3. It is also used in radar and navigation systems.

1.5 GSM(GLOBAL SYSTEM FOR MOBILE COMMUNICATION)

A mobile phone uses GSM technology, which is an open and digital cellular protocol. There are four different frequency bands used by this technology, including 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz. It combines FDMA and TDMA.
During the early 1970s, Bell Laboratories developed a cell-based mobile radio system that formed the basis for GSM.
Four separate components make up GSM networks:

- The mobile phone
- The base station system (BSS)
- The network switching system (NSS)
- The operation and support system (OSS)



The base station system (BSS) carries data between the cellphones and the network system servers. It comprises two main components: the base transceiver station (BTS) and the base station controller (BSC).

In GSM networks, the NSS, also known as the core network, tracks the location of callers in order to provide cellular services. It includes a mobile switching centre (MSC) and a home location register (HLR). A mobile service switching centre is like a standard ISDN or PSTN switching node

1.5.1 Advantages of GSM:

1. GSM provides worldwide roaming for its customers.
2. Due to its unique devices and facilities, GSM is extremely secure.
3. Spectrum efficiency and clear voice calls.
4. You can send short messages, view your caller's ID, place a call on hold, and forward your calls.
5. AD is available on Integrated Services Digital Network (ISDN) and other telephone company services.

1.5.2 Disadvantages of GSM:

1. As multiple users share the same bandwidth, bandwidth lag can occur.
2. Due to the interference that is caused by pulse transmission technology, some electronics, such as hearing aids, cannot be used in certain places, such as hospitals, airports, and petrol pumps.
3. Repeaters are needed to increase coverage.
4. The maximum call range of GSM is 35 km.
5. The data of users is not encrypted end-to-end.

EXERCISE 1

Question1: How do you define mobility in mobile computing?
Question 2: What are the uses of mobile computing?
Question 3: List the advantages of mobile computing.
Question 4: Describe multiplexing and its uses.
Question 5: What are the different types of multiplexing?
Question 6: Describe in detail the advantages and disadvantages of the different types of multiplexing.
Question 7: What is the full form of GSM?
Question 8: List the components of GSM.
Question 9: List the advantages and disadvantages of GSM.

1.6 GPRS AND 2.5G

As part of GSM's global system for mobile communications (GSM), General Packet Radio Service (GPRS) is a packet-oriented mobile data standard. As a response to CDPD and i-mode packet-switched cellular technology, the European Telecommunications Standards Institute (ETSI) developed GPRS. The 3GPP is now responsible for maintaining it.
A GPRS network is a packet-switching communications protocol that uses the best-effort packet switching method.

The technology allows mobile data to be transmitted and received more efficiently, more quickly, and more cheaply. Mobile devices using GPRS are always connected to the internet, making them always online and liable for data usage charges. When used, the device only keeps the connection busy. So, capacity is better utilized, and more data can be exchanged simultaneously. There is a maximum speed range of 7 KB/s to 14 KB/S on GPRS. It is called **2.5G**, which is the state of wireless technology between the second and third generations of wireless technology: before and after General Packet Radio Services (**GPRS**).
A generation is not official. It is called so because it is in the middle of 2G and 3G. There is still support for 2G and 3G within M2M.

In contrast to the circuit-based switching protocols of 2G, GPRS uses packet-switching communications. Due to this, data delivery is best-effort; there can be a variation in latency and deliverability. The Quality of Service (QoS) of GPRS is difficult to manage due to the number of concurrent users.

In the past, GPRS (2.5G) speeds have been quoted over 2G networks; GPRS can theoretically transmit around 120 kilobits per second over 2G networks. In real-world conditions, you can expect speeds of 20-50 kbps. Latency may vary, but typically will range from .5 to 1 second.

1.6.1 Features of GPRS

1. It is a packet-based data network that is well suited for non-real-time Internet applications, such as retrieving email, fax messages, and asymmetric web browsing, where users download more data than they upload.
2. Multi-user GPRS networks share individual radio channels and time slots among users.
3. In contrast to HSCSD, GPRS can support many more users, but in a burst manner.
4. An IS-136 or GSM-based packet network is provided by the GPRS standard. For better packet data access, GPRS retains the original modulation formats of 2G TDMA while using a completely redesigned air interface.
5. A user can achieve as much as 171.2 kbps using all 8 Time-slots of an individual GSM radio channel.
6. Data payloads carried in GPRS must be error corrected by the applications.

1.6.2 Services offered by GPRS

By extending the GSM Packet circuit switched data capabilities, GPRS can deliver the following services:

1. SMS messaging and broadcasting
2. Multimedia messaging service (MMS)
3. Push-to-talk over cellular (PoC)
4. Instant messaging and presence—wireless village
5. Point-to-point (P2P) service
6. Through wireless application protocol (WAP), smart devices can access the Internet
7. Point-to-multipoint (P2M) service
8. If SMS over GPRS is used, an SMS transmission speed of about 30 SMS messages per minute may be achieved. This is much faster than using the ordinary SMS over GSM, whose SMS transmission speed is about 6 to 10 SMS messages per minute.

1.7 THIRD GENERATION (3G)

In the early 1980s, the International Telecommunication Union (ITU) carried out research and development on 3G technology.
This new generation of wireless technology allows handheld devices to access high-speed data and voice services. 3G networks will provide multimedia services combining voice and data.

1.7.1 3G WiFi

A device that includes cellular data service of the third generation (3G) as well as Wi-Fi is a 3G Wifi. In recent years, Apple's iPad and Amazon's Kindle readers have been among the first to offer 3G and Wi-Fi connectivity. When a mobile phone is equipped with both 3G and Wi-Fi, it is possible to access the Internet regardless of where the user is located. When the mobile phone is equipped with only Wi-Fi, the user is required to be near a Wi-Fi hotspot at home, work, or a café or hotel.

1.7.2 Advantages of 3G

1. Overcrowding in existing systems can be relieved by adding new radio spectrum.
2. The capacity, security, and reliability of the network is increased.
3. A device that is always online, 3G uses IP connectivity, which is packet-based (not circuit based).
4. As the third generation of data communication and mobile phone standards, 3G offers higher bandwidth for video and web-based applications. It offers faster data transfer and better voice quality than 2G, 2.5G, GPRS, and 2.75G EDGE networks.
5. Wireless voice, video, and data services are included in 3G Services.
6. The 3G network supports services with at least 144 kbit/s of information transfer rate. As a result of further 3G releases, known as 3.5G and 3.7G, smartphones as well as mobile modems in laptop computers can also access mobile broadband of several Mbit/s. As a result, it can be used for wireless voice calls, mobile Internet access, fixed wireless Internet access, video calls and mobile TV services.
7. There are several 3G systems, including the Universal Mobile Telecommunications System (UMTS), Wideband CDMA (W-CDMA), and Code Division Multiple Access 2000 (CDMA2000).

1.7.3 Disadvantages of 3G

1. Requires different handsets.
2. Insufficient bandwidth.
3. High power consumption.
4. It is very expensive to upgrade base stations and cellular infrastructure to 3G.
5. Closer base stations are required making it more costly.
6. Costly spectrum-licence, expensive network deployments, and subsidies for handsets.

1.7.4 3G is being phased out for what reason?

It is expected that AT&T will terminate its "third generation" telecommunications network to devote more bandwidth to developing much more advanced 5G networks. People who use 3G or some 4G devices without VOLTE (Voice over LTE) won't be able to access the Internet.

1.8 FOURTH GENERATION (4G)

In contrast to 3G mobile networks, 4G mobile phones offer broadband cellular network services. A fully IP-based cellular communication system is provided. International Telecommunication Union (ITU) specifications govern the capabilities provided by IMT-Advanced.
4G connections connect mobile devices to mobile networks via an antenna that transmits radio waves. MIMO (Multiple Input Multiple Output) and OFDM (Orthogonal Frequency Division Multiplexing) are used for 4G transmission and reception. Compared to 3G, MIMO and OFDM provide more capacity and bandwidth. TDMA (Time Division Multiple Access) and CDMA (Code Division Multiple Access) are the primary technologies that powered 3G. OFDM provides higher speed than those technologies.

1.8.1 Features of 4G Network:

1. The network provides voice, data, signals, and multimedia transmission over IP packet switches.
2. According to the IMT-Advanced specifications, high-mobility stations such as trains, cars, and residences should have peak data rates of 100Mbps, while low-mobility stations such as residences should have peak data rates of 1Gbps.
3. 4G networks must also be capable of 1 Gbps downlink over 67 MHz bandwidth or less.
4. It provides uninterrupted high quality services 24 hours a day, 7 days a week, regardless of location or time.

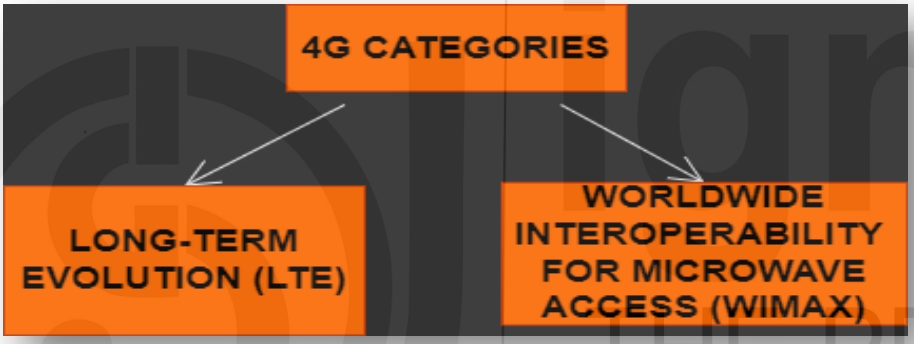
1.9 LONG-TERM EVOLUTION (LTE)

Long-term evolution (LTE) technology is an enhancement to 3G. UMTS/HSPA and GSM/EDGE technologies combine to provide high-speed mobile communication. In comparison to third-generation (3G) wireless technology, LTE (Long-Term Evolution) offers increased network capacity and speed for cellphones and other cellular devices. Compared to 3G, LTE is capable of higher peak data transfer rates, initially up to 100 Mbps downlink and 30 Mbps uplink.
LTE is often referred to as 4G LTE and is the next step in the evolution of mobile technology. It follows the specifications of 2G GSM and 3G UMTS.

According to the International Telecommunication Union (ITU), LTE is not true 4G. It was initially defined as a standard that would enable stationary users to consume a data rate of 1 Gbps and mobile users to consume 100 Mbps.

1.9.1 Features of LTE

1. In 2021, LTE's global average download speed was 17 Mbps, and its average upload speed was 12 Mbps.
2. The voice over LTE (VOLTE) technology allows users to talk without jitter or lag.
3. Compared to standard LTE, LTE-Advanced devices offer two to three times faster download and upload speeds.
4. By combining frequencies from multiple component carriers, LTE-Advanced handsets improve signal, speed, and reliability, adding bandwidth of up to 100 MHz across five component carriers (bands).



1.10 WORLDWIDE INTEROPERABILITY FOR MICROWAVE ACCESS (WIMAX)

In some cases, WiMAX is referred to as 4G because it is a standard for mobile wireless broadband access (MWBA). With 20 MHz wide channels, peak downlink data rates are 128 Mbps and uplink data rates are 56 Mbps. It is based on the IEEE 802.16 standard and is a wireless microwave technology. WiMAX forum first published it in 2001, the version that is now known as fixed WiMAX.

1.10.1 Features of WIMAX:

1. Broadband wireless access (BWA) networks will be advanced by this initiative.
2. In the initial version of WiMAX, data rates were 30-40 Mbps, but in 2011, the updated version offered 1 Gbps data rates.

3. A few similarities exist between WIMAX technology and Wi-Fi technology, hence its nickname of "Wi-Fi on steroids." However, WiMAX provides much higher data rates, is used for outdoor networks, and uses IEEE 802.16 standards rather than IEEE 802.11 standards.
4. As per user requirements, bandwidth is dynamically allocated from 2 GHz to 11 GHz.

Exercise 2

Question 1: Differentiate between GSM and GPRS.

Question 2: Explain the services offered by GPRS?

Question 3: Explain the disadvantages of 3G?

Question 4: What is the difference between 3G and 2.5G?

Question 5: Explain WiMax?

Question 6: What is the difference between 4G and 4G-LTE?

Question 7: What are the primary technologies to power 3G?

1.11 SUMMARY

A wireless-enabled computer or mobile device (or a combination of both) can transmit data, voice, and video without needing to be connected to a fixed physical network.

Mobile Computing has 2 types of mobility; user mobility and device mobility.

In mobile computing, communications, and computer networks, multiplexing can be used to combine analog or digital signals.

Multiplexing consists of three categories; TDM, FDM and WDM.

Mobile phones use GSM technology, which is an open and digital cellular protocol.

As part of GSM's global system for mobile communications (GSM), General Packet Radio Service (GPRS) is a packet-oriented mobile data standard.

3G networks provides multimedia services combining voice and data.

4G connections connect mobile devices to mobile networks via an antenna that transmits radio waves.

In comparison to third-generation (3G) wireless technology, LTE (Long-Term Evolution) offers increased network capacity and speed for cellphones and other cellular devices.

WiMAX is referred to as 4G because it is a standard for mobile wireless broadband access (MWBA).

1.12 FURTHER READINGS

1. Code Division Multiple Access Example

https://www.youtube.com/watch?v=Ex31vvIEzZ0

2. Mobile Computing and Wireless Communication

https://slidetodoc.com/mobile-computing-and-wireless-communication-2170710-unit-1/

3. Wireless Communication & Mobile Programming

   https://slidetodoc.com/wireless-communication-mobile-programming-unit-1-mobile-computing/

4. "Mobile Computing" by Asoke K Telukder, Roopa R Yuvagal, TMH

5. FUNDAMENTALS OF MOBILE COMMUNICATION by Mehaboob Mujawar, Jafar A. Alzubi

6. Introduction to Mobile Communication

   S Sureshkumar, Fr. J. Janet, APS. Anandaraj

7. Wireless And Mobile Communication by Sanjeev Kumar, New Age International (P) Ltd., Publishers

8. MOBILE AND WIRELESS COMMUNICATION

   Leena R. Mehta

9. Mobile Communication

   by: Behera G. K.

UNIT 2 INTRODUCTION TO MOBILE COMPUTING ARCHITECTURE

2.0 INTRODUCTION

Nowadays, mobile computing is one of the fastest-growing technologies. A major strength of this service is its broad reach and ease of use. In addition to the computing requirements and new apps in mobile devices, the number of mobile device users is also growing exponentially, as is the demand for resources for them. As a result, the design and construction of a mobile computing architecture that is efficient, effective, scalable, and secure is one of the most challenging aspects of the mobile computing environment.

2.1 OBJECTIVES

At the end of the Unit, you shall be able to:

1. Understand various types of mobile computing networks that exist.
2. Understand the development of novel applications, the use of smart phones and the Internet, enterprise solutions, mobile personal cloud, mobile payments, and mobile wallets.
3. Understand Three-tier architecture and N-tier architecture for mobile computing.
4. Understand design considerations in mobile computing including operating systems, languages, protocols, software layers, and data synchronization and dissemination.
5. Understand how to incorporate mobile computing into existing applications through the Internet.
6. Understand various limitations of Mobile devices.
7. Understand Mobile computing security.

2.2 MOBILE IP, CELLULAR AND WLAN WI-FI IEEE 802.11x NETWORKS

Mobile IP: A request for comments (RFC) 2002 was issued by the Internet Engineering Task Force (IETF) defining mobile IP as an open standard. All media-supporting IPs also support mobile IP due to it being based on the Internet protocol (IP). Agents at home and abroad provide the mobile IP service through mobile IP networks. Distributed computing and mobile devices form mobile networks.

2.2.1 Cellular Network

There is a base station for each cell. Mobile devices use base stations as access points. A base station's coverage area defines a cell. Each cell has a defined coverage area. Wireless communication takes place between a mobile device and a base station within the cell boundaries. Each cell in a cellular network has an interconnected base station.

Every mobile service region consists of a number of cells. Based on the technology and frequency bands used within a cell, the size of a cell varies. As an example, the cell radius in CDMA 950 MHz networks is 27 km, while it is 14 km in CDMA 1800 MHz networks.

Assuming the cells are hexagonal in shape; cell A0 is surrounded by the boundaries of 6 cells: A1, A2, A3, A4, A5 and A6.

A0, A1, A2, A3, A4, A5 and A6 have base stations BS, BS1, BS2, BS3, BS4, BS5 and BS6, respectively. An area of coverage defined by A's cell boundaries is covered by BS.
An ith base station, BSi, can be considered as an access point for the services in the region Ai. Cells are centered on the base station. The base station is the only point of communication between mobile devices within a cell.

A guided network (wired or fibre-based) or wireless network connects the base stations. Alternatively, stations can connect to the public switched telephone network (PSTN). Switching is the act of establishing a connection and maintaining it until it is disconnected or switched off. There are a number of public services that provide the PSTN to a mobile service provider. Public telephone networks are extensive in the public service.

Transceivers (mobile phones) on a multi-cell cellular network must switch between cells when they move from one place to another. An initial cell's base station hands over a mobile device when it reaches a cell boundary. In order to switch to the next cell, the device connection is handed over to the neighboring base station.

Depending on the cellular network type (GSM or 3G CDMA), different handover mechanisms are used. Mobile devices switch from one channel to another without disrupting ongoing communication.

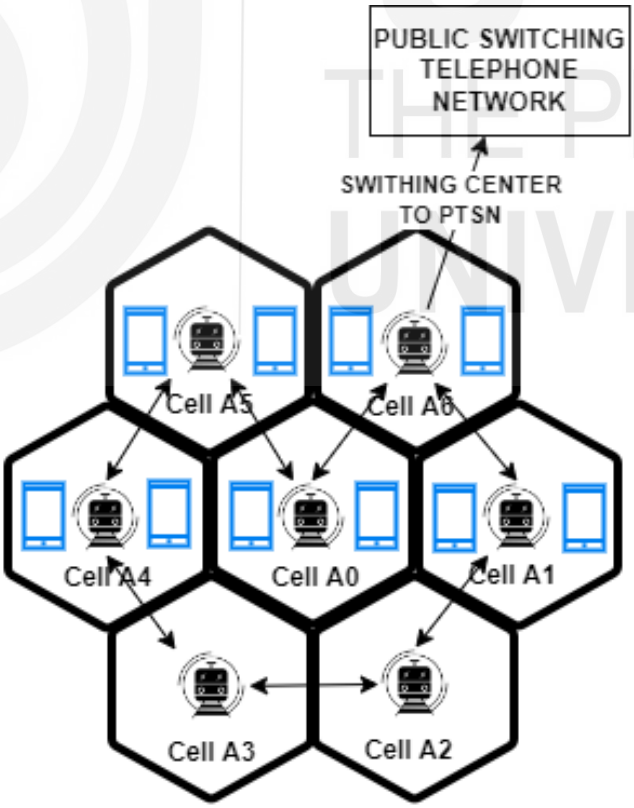


Fig 1: Mobile communication using the cells A1, A2, A3, A4, A5, and A6 of a cellular network

Frequency Reuse and Adjacent Channel Network

GSM communication technology uses different frequency bands for neighboring cells. Cells adjacent to the immediate neighboring cell can reuse the frequencies.

Throughout a cellular network, cells surround each other. Interference is caused when the same frequency band is used at the same time and at the same point. A cell's frequency differs from that of its neighbor. In FDMA, cells that reuse the same frequency channel must have at least one gap between them. It is necessary to use different frequencies for cells A1, A2, A3, A4, A5 and A6 if cell A0 uses frequency f0. By doing so, different cell signals will not interfere with each other. Whenever two frequencies are equal or integral multiples of one another, interference occurs.

Consider the cell A0 uses frequency f0 and cell A1 uses f1, cell A2 uses f2 then cell A3 can reuse f1. This is because; A1 and A3 do not lie adjacent to each other, so there is a one-cell gap between them. Similarly cell A4 can reuse f2, cell A5 can reuse f1 and cell A6 can reuse f2. Whenever frequencies are reused, they need to be allocated separately, like f0, f1, and f2. There is a 1/3 frequency reuse factor. Keeping at least one cell separation allows frequency reuse in this case. A cell gap therefore exists between cells that reuse the same frequency channel.

It is possible to have a frequency reuse factor (u) of 1/3, 1/4, 1/7, 1/9, or 1/12. Using more frequencies in the cells can also reduce cell sizes.
Frequency reuse formula: distance $d = r \sqrt{(3 \times n)}$
In this equation, r refers to the distance between the center of the cell and the boundary, and n refers to the number of cells surrounding the cell.

From the perspective of the base station (BS), each cell can be divided into sectors. Suppose that a BS uses m antennae per sector. Different antennas can use the same frequency and point in different directions. During space division multiplexing, the cell divides its space. As a result, the frequency reuse factor will be m/u. Reuse patterns of 3/4 are used in GSM mobile networks. Consider a GSM service with a total bandwidth of b. Therefore, b/u is the number of frequency channels available. In space division multiple access (SDMA), each sector can use bandwidth b, which is equal to b/m x u.

A set of frequency channels can, therefore, be used by GSM mobile service networks. Cells adjacent to each other are allocated different frequency channels.

A CDMA network uses a spread spectrum (SS), which means that a range of frequencies can be used; however, they are used in conjunction with a coding scheme. For example a school proposes three colors of dresses and each class uses these three colors. Thus, the scheme can be: class 1 has blue on Mondays, black on Tuesdays and purple on Wednesdays. For class 2, it can be black on Mondays, purple on Tuesdays, blue on Wednesdays and so on. Each user's channel,

or frequency in the spectrum, is coded differently, so all frequencies are available, but with a different coding scheme.

A frequency reuse factor of 1 is applied for each sector and each cell when the same spectrum is used, but the code used to encode the chipping frequencies or frequency hopping sequences is different.

There is a high data transfer rate between pre-4G and 4G services. Using multiple antennas that share bandwidth, multiple antennas communicate coherently with the user's mobile device. Distance and path length increase incoherency. Pico cells reinforce the coherency and relay it to the devices when each cell sector is divided into picocells. As a result, pre-4G services divide networks into narrow regions by using picocells, and further divide smaller networks by using femtocells. It is possible that one picocell corresponds to one floor of a building.

Capacity Enhancement in Networks

Frequency reuse enhances capacity. Additionally, multiplexing increases capacity. It is possible to share data transmission space, time, frequency, or code between different channels, users, or sources. In terms of space, time, and frequency, multiplexing (SDMA, TDMA, and FDMA) determines how these resources can be shared.

Enhancement of capacity caused by frequency reuse is given by k x m x u. In this equation, k is the enhancement due to multiplexing, m is the number of sectors within a cell, and u is the number of adjacent cells.

The beams transmitted by a sector antenna can be divided into micro sectors. Signals radiated from the antenna are referred to as beams. Further capacity can be enhanced by using switched beam smart antennae. There are p different directions in which an antenna can radiate a beam. Frequency reuse increases capacity by p x k x m x u.

Co-Channel and Adjacent Channel Interference

Two signals of the same frequency or very close frequency superimpose at an instance at a place when they use two channels, and when the phase difference between both signals is 180 (or odd multiples of ∏), then the amplitudes of the signals subtract, resulting in 0. In a case where the phase difference is 0° (= even multiples of ∏), the amplitude adds up and the resultant amplitude is twice the amplitude of the individual signals.

It is possible for sources to use several channels at the same time. Signals with close frequencies

are susceptible to interference. The phenomenon is known as co-channel interference (cross-talk). The interference effects between two channels with P1 and P2 are negligible when P2 <<P1.

Let's look at an example. Interference effects between two people speaking near each other in a feeble voice and one in a louder voice are negligible. Re-using frequencies and high co-channel power levels increase interference between co-channels.

Signals from nearby sources cause adjacent channel interference.

Two modulated sources transmitting in the same band overlap their frequencies, causing narrow band interference. Additionally, interference between adjacent channels can be caused by insufficient frequency control or tuning in a source.

As the individual spectral carriers have reduced power, spread spectrum reduces co-channel interference. As a result of the spread spectrum's frequency bands, power is distributed over a greater number of frequencies. Due to the large number of frequencies used in narrow band interference, it has too little effect.

Cellular Broadband

There are now 3G-enabled cell towers that support EV-DO, HSDPA, and HSUPA. Therefore, mobile broadband access is supported by the service providers. It is possible to accomplish this with the help of a USB cellular modem or a cellular broadband router. Multiple computers can be connected by a router. A USB cellular modem connects to a computer. As with a pen drive, the modem is attached via a USB port.

Mobility Management

In order to maintain continuous (seamless) signal connectivity when a mobile device moves from a cell, Ci, or network Ni, to a cell, C1, or network N1, mobility management is necessary. The following must be present to guarantee ongoing connectivity:

1. Management of the infrastructure for setting up and maintaining the links between networks Ni and N1 or cells Ci and C1.
2. When a mobile device's connection with the i^{th} cell is transferred (on handoff from the i^{th} cell) and registered at the new (j^{th}) cell, location and registration management by handoff for cell transfer is used.

2.2.2 WLAN Wi-Fi IEEE 802.11x Networks

Wireless local area network (WLAN) sets of well-liked standards have been suggested for mobile communication. The standards mentioned here are IEEE 802.11a, 802.11b, 802.11g, 802.11i, and 802.11n. When mobile devices, iPads, laptops, desktop computers, or printers connect to an access point utilizing a protocol standard outlined in IEEE 802.11x, where x = a, b, g, I or n, a wireless LAN has been created. WLAN is a Wi-Fi-based wireless network service.

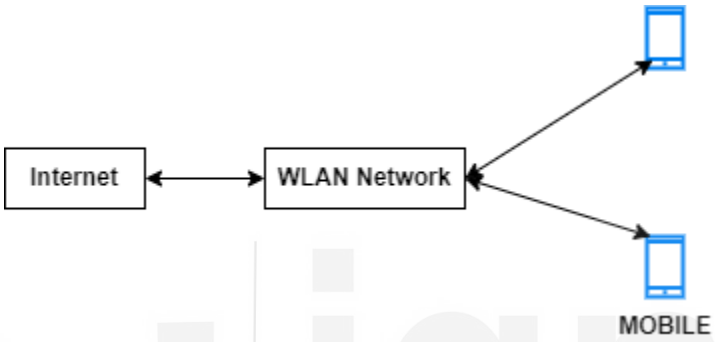


Fig2: 802.11 WLAN communications

WLAN and Internet Access

Communication between mobile devices and the Internet is established by the network. Mobile devices and the Internet can communicate. Thanks to the network.

1. An iPad, tablet, or other mobile device connects to the Internet by way of an Internet service provider using Wi-Fi. A mobile device, such as a tablet, iPad, or laptop, connects to a hotspot-style access point. A router connects the host LAN, which is connected to the Internet by the access point, to the Internet. As a result, connectivity develops throughout the Internet. Computers, mobile devices, and two LANs.
2. Web content is sent to mobile phones' small-area display devices using the wireless application protocol (WAP). The WAP format is used by the service providers to format material.
3. The screens of modern mobile devices, tablets, and iPads are larger. Additionally, the majority of modern devices can connect to the Internet via HTTP using either a mobile data service provider or an Internet service provider. Many modern devices support both HTTP and WAP. For instance, NTT DoCoMo in Japan developed Internet in Mobile Mode (i-Mode), which was a hugely well-liked wireless Internet service for mobile phones.

Standard	Extension	Description
802.11	a	There may be more than one physical layer in 5 GHz due to MAC layer operations (infrared, two 2.4 GHz physical layers). The layers enable both mobile ad hoc network (MANET)-based architecture and infra structure-based architecture. At data rates of 6 Mbps and 9 Mbps, OFDM modulation is used. The supported data rates range from 54 kbps to a few Mbps.
	b	It uses DSSS/FHSS modulation at 2.4 GHz and works at 54 Mbps. Additionally, it supports Bluetooth (IEEE 802.15.1)-based software and the HIPERLAN2 (HIPERformance LAN 2) OFDMA physical layer for use with short-range wireless networks. It offers secure Wi-Fi connection. 1 Mbps (Bluetooth), 2 Mbps, 5.5 Mbps, 11 Mbps, and 54 Mbps are the available data rates (HIPERLAN 2)
	g	It runs at 2.4 GHz and 54 Mbps. It is compatible with 802.11b and used for many new Bluetooth applications. OFDMA is replaced by DSSS.
	i	The AES and DES security standards are provided.
	n	A new multi-streaming modulation method is IEEE 802.11n. Numerous new capabilities are included, including multiple-input multiple-output (MIMO) antennae. Using several 54 Mbps streams, data rates can be increased to 600 Mbps. It allows the usage of four spatial streams with a carrier frequency of 2400 MHz and a channel width of 40 MHz. It supports 64 QAM, QPSK, and BPSK.

Table 1

2.3 AD HOC NETWORKS

A temporary variety of local area network is an ad hoc network (LAN). An ad hoc network turns into a LAN when it is permanently installed. An ad hoc network may accommodate multiple users at once, although performance may suffer. As long as the hosting device has internet connectivity, users can also use an ad hoc network to connect to the internet. This could be

helpful if numerous individuals need to access the internet but there is only a limited amount of internet connectivity in a certain location.

Through an ad hoc network, multiple devices can share the host device's internet connectivity. Jobs that handle this kind of network are often well-paid by employers, especially in professions that require a lot of travel.

Security is one of the main issues with an ad hoc network. Cybercriminals can typically connect to a wireless ad hoc network and, consequently, to the device if they come within signal range.

The network name cannot be disguised if users are in a public area since users cannot prevent their SSID broadcast in ad hoc mode. Ad hoc networks are not always appropriate because of this.

Ad hoc connections, however transitory and only reachable within 100 metres, can be useful in some circumstances. Attackers are unable to access a gadget from a distance and are limited in the amount of time they have to plot their attack.

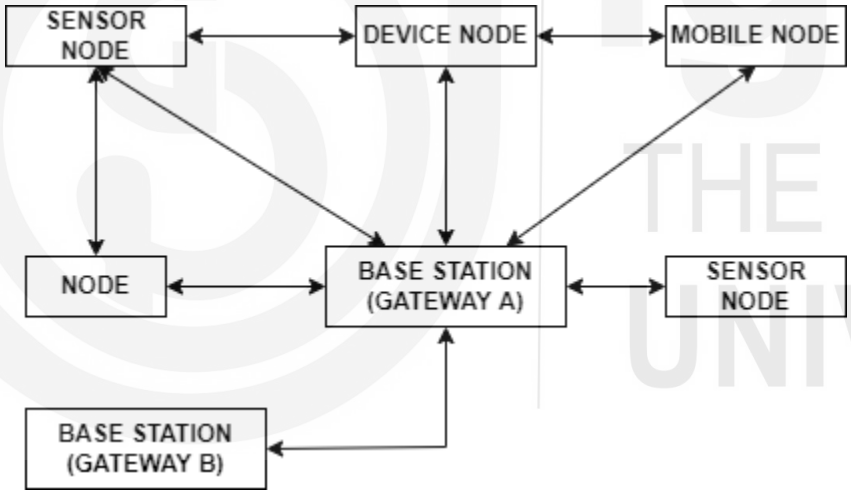


Fig3: Direct communication between sensor nodes and mobile nodes utilizing a base station as a gateway

The above diagram demonstrates how a base station is used to facilitate communication between the nodes, device node, mobile nodes, and sensor nodes. Gateways are acted upon by the base stations.
Each node has the ability to discover itself and configure itself. Every node has a router capability. A router locates the additional communication channels that are available. Ad hoc networks are used in a mobile context for routing, target detection, service discovery, and other requirements.

2.4 MOBILE COMPUTING OPERATING SYSTEM

An operating system is necessary for mobile computing. Without taking into account the capabilities and specifications of the hardware, an operating system (OS) enables the user to run an application. Additionally, it offers tools for organizing various tasks into a system's schedule. Even the personal information manager (PIM) and APIs for using SMS, MMS, GPS, and other apps are provided by an OS.

Tasks and memory can be managed by an OS using tools including creation, activation, deletion, suspension, and delay. It offers the features necessary for the system's many tasks to be synchronized. There may be several threads for a task. It offers thread synchronization and priority distribution.

Additionally, an OS offers interface for software at the application layer, middleware layers, and hardware devices to communicate with one another. It makes it easier for software components to run on a variety of hardware. For the device's graphic user interface (GUI), an OS offers programmable libraries. Many user-operated devices require User application's GUIs, Voice User Interface (VUI) components, and phone Application Programming Interface (API).

Device drivers for USB, keyboard, displays, and other devices are also provided by an OS. Middleware, applications, and a fresh environment for developing applications are all provided by mobile OS.

EXERCISE:

Question 1: What are cells and base stations?

Question 2: Describe how the cellular network operates. How a network's capacity is increased using the provided set of frequencies?

Question 3: What are the differences in characteristics provided by Bluetooth, ZigBee, and IrDA?

Question 4: Give an explanation of the wireless personal area network protocols (WPAN). Offer some WPAN network applications for the house.

Question 5: When is NFC used? Describe the uses for NFC.

2.5 CLIENT SERVER COMPUTING USING MOBILE

Think of a network of nodes that are spread out (computers and computing devices). A node may be either a client or a server depending on the network architecture. Application software is run on a client node and is dependent on server node resources (files, databases, Web pages, other resources, processor power, or other devices or computers connected or networked to it). The server node has more computer power and resources than the client nodes. The client-server computing architecture is the name given to this design. It differs from peer-to-peer design, where each network node has a similar set of resources and the different nodes rely on one another for those resources.

A distributed computing architecture known as client-server computing uses servers and clients as its two types of nodes. The server can be asked by a client for information or responses, which the client can subsequently employ in calculations. The client can cache these records on the client device or access them directly from the server. The data may be accessible at the client's request, via broadcasts, or by server distribution.

Due to their limited resource availability, mobile devices operate as client nodes. Several devices are connected to a server. Both the client and the server may be running on the same computer system or on distinct ones. An N-tier design for client-server computing (N = 1, 2) is possible. The number of tiers, N = 1, when the client and server are on the same computing system (not on a network). N=2 is the case when the client and the server are on different computing platforms connected to the network. N > 2: if the server is connected to or connected through networks to other computing systems that supplies the server with additional resources for the client. N> 1 denotes a connection between a client device at tier 1 and a server at tier 2, which may then connect to tiers 3, 4, and so forth.

For data, the client device synchronizes or connects to higher levels. To obtain client requests at the server or server responses at the client, a command interchange protocol (like HTTP) is used. The following list describes 2, 3, or N-tier architectures for client-server computing. A connecting, synchronizing, data, or command interchange protocol is used to link each layer to the others. The Java Remote Method Invocation (RMI) protocol and the C++-based remote procedure call are two examples of data or command transfer protocols (RPC).

Client-Server Two-tier Architecture

An application server may be required by a particular application to distribute a local copy of data to numerous devices. On the devices, the application can now execute independently without the need for run-time retrieval.

Through a synchronization API, the multiple APIs communicate with one another. When records are amended at the server end, synchronization means that the cached copies on the client

devices should also be updated. Since different devices may use different platforms, the APIs are created as independently of hardware and software platforms as possible.

Three-tier Architecture for Mobile Computing

In three-tier computer architecture, the application interface, functional logic, and database are maintained at three distinct tiers. Through a synchronization-cum-application server at tier 2, data records at tier 3 are transmitted to layer 1 of the data chain. With the help of business logic, the synchronization-cum application server's synchronization and server programs retrieve data records from the enterprise layer (tier 3). Using a connectivity protocol, the enterprise tier connects to the databases and transfers the database records to tier 2 in accordance with the business logic query. Additionally, a three-tiered data hoarding system is displayed. A middle server known as the synchronization server transmits and synchronizes copies to numerous mobile devices. For the applications 1 to j, local copies of the databases 1 to I are stored on the mobile devices. In the image, an enterprise database connection to a synchronization server is also shown. This server synchronizes the enterprise database server with the local copies needed by the apps. In the event of a Web-client at tier 1, HTTP can also be utilized as a synchronization protocol.
Internet-based communication from Tier 1 to Tier 2 allows for further connectivity to be created using HTTP or HTTPS.

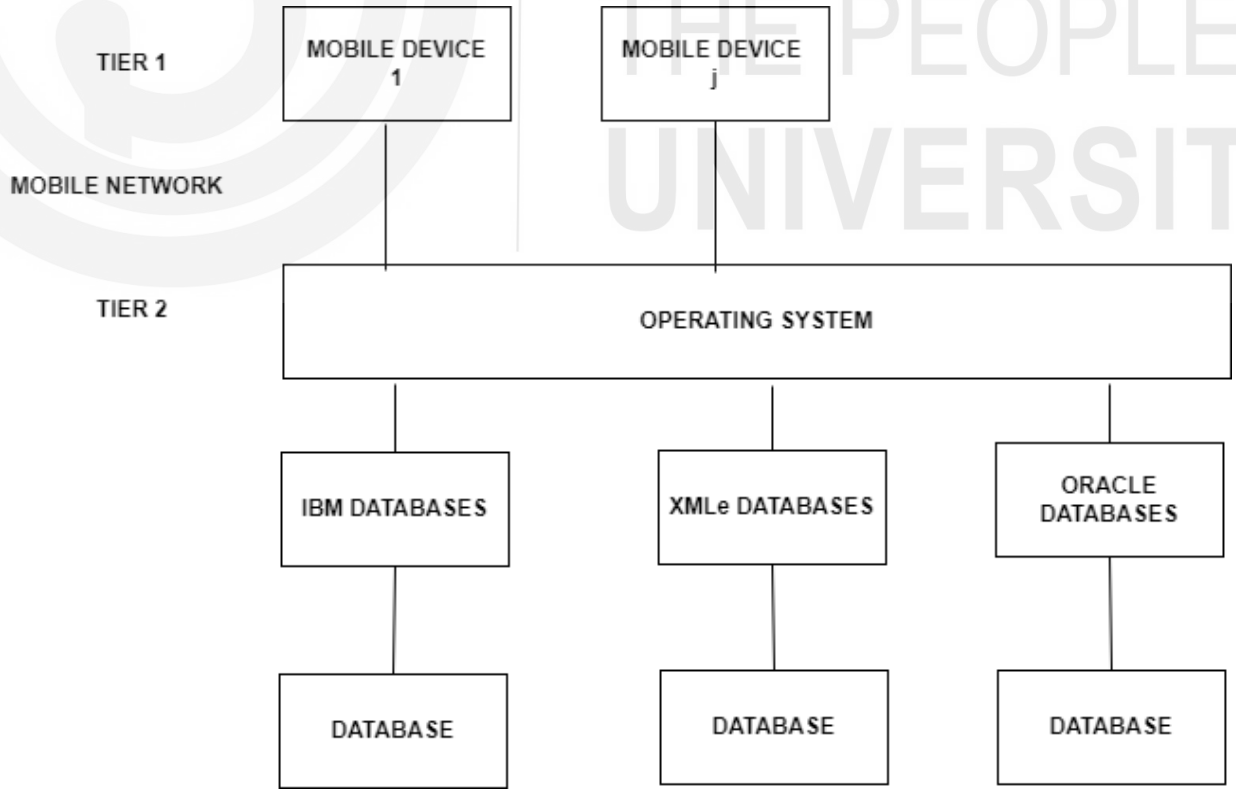


Fig 4: Two-tier client server application

2.6 MOBILE COMPUTING ARCHITECTURE

The architectural layers of mobile computing devices, mobile computing on the device using APIs are all described in this part of the Unit.

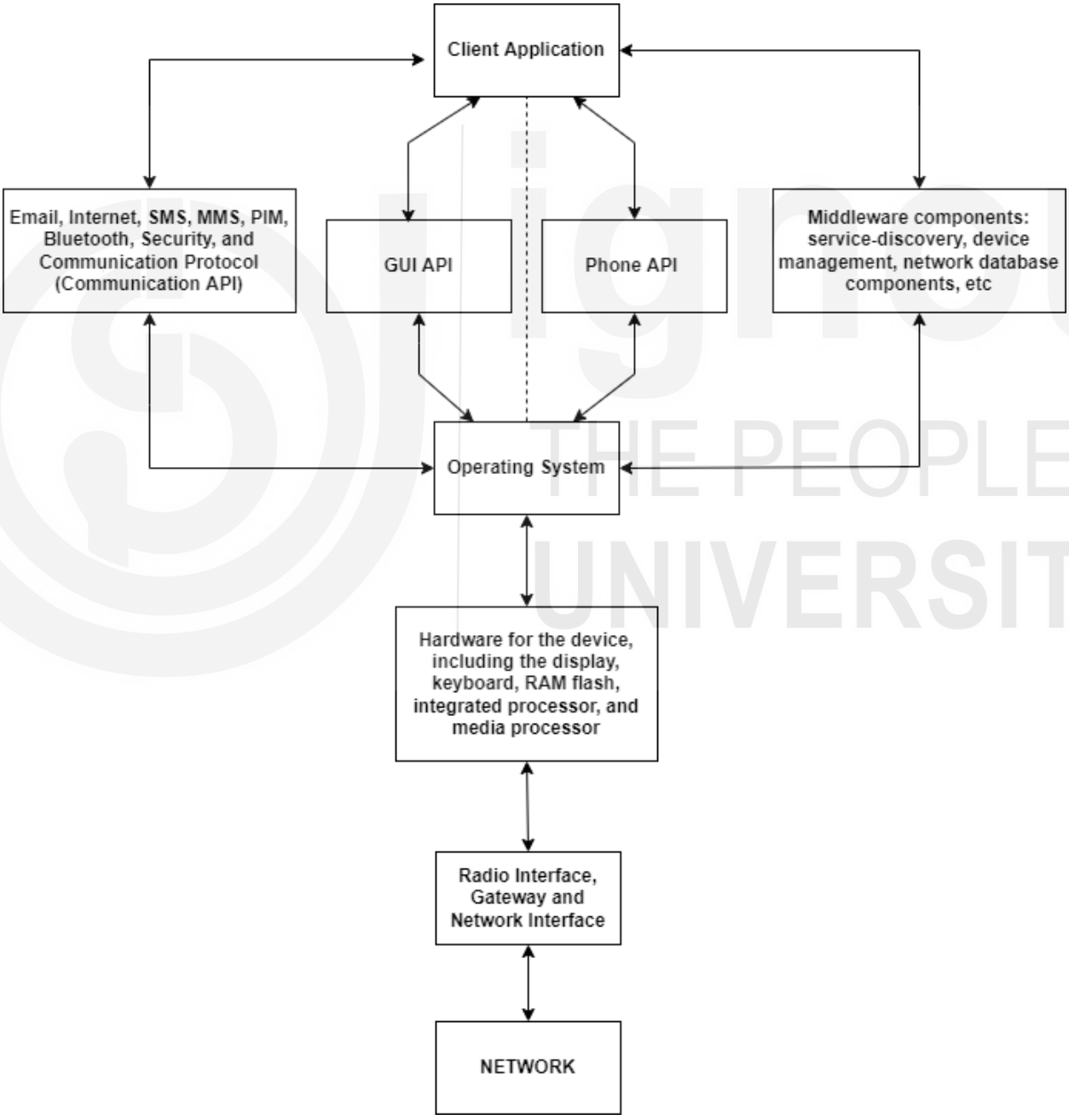


Fig 5: Mobile Computing Architecture

2.6.1 Design considerations for Mobile Computing

The architecture of mobile computing relates to the several layers that are established between user applications, interfaces, devices, and network hardware. For systematic calculations and access to data and software objects in the layers, a clearly defined architecture is required. The software components and APIs are deployed by an application. For instance, the communication APIs in a mobile smartphone's Internet, PIM, SMS, MMS, Bluetooth stack, security, and communication protocol stack. The client APIs can be viewed as one of the architectural layers. In addition to updating databases, managing devices with remote server software, performing client-server synchronization, and adapting applications to certain platforms and servers, middleware components also locate services and connect client and network services. Between the program and the hardware lies a layer called an OS. It makes running the software easier, hides hardware characteristics, and offers numerous OS functionalities (e.g., device drivers). A program can directly use an OS function, for instance, the time delay (3000) function, which delays the execution of subsequent instructions by 3000 clock ticks.

2.6.2 Mobile Computing using APIs

The following are a few examples of mobile computing APIs: voice recognition, text-to-speech conversion, voice-based dialing, camera, album, video clip recorder, and Wi-Fi network access point connectivity.

EXERCISE:

Question 1: A client-server computing architecture with the database at the application tier should be displayed. When the application server retrieves the data from the enterprise server layer, how does this architecture change?

Question 2: Explain the four-tier architecture. In client-server architecture, how are multimedia databases used to serve a mobile device?

Question 3: What software components and layers are required in a mobile computing device?

Question 4: Explain the functionality of an OS in a mobile system.

Question 5: Describe a unique mobile application that interests you. What further software components are included in this application?

2.7 DESIGN CONSIDERATIONS FOR MOBILE COMPUTING

The architectural specifications for programming a mobile device are described in this section. It gives an overview of the programming languages used to create the software for mobile devices. To run the software components on the hardware, an OS is necessary.

1. **Considerations for Frameworks and Programming Languages:** The mobile computing architecture employs a number of programming languages. Java is one of the most used languages for mobile computing. This is due to Java's most significant feature, platform independence, which means that Java program codes are independent of the CPU and OS utilized in a system. This results from a typical compilation into bytes.
   J2SE is the name of Java 2's standard edition. There are two editions with a small memory footprint: Java2 Micro edition (J2ME) and Java Card (Java for smart card). These are the two most popular languages for mobile computing and creating apps for platforms used by mobile devices. Mobile service apps that are Web- and enterprise server-based employ Java 2 Enterprise Edition (J2EE).
   The other two widely used programming languages are C# and JavaScript. Program compilation for these languages depends on the CPU and operating system being utilized. The benefit of C# is that it makes it possible to build Uls, and JavaScript makes it possible to create contents on the fly.
   Server communications and client messages are presented using the markup language XML HTML5.
   Popular mobile application frameworks like Python 2.7 and 3.0 support scripting languages like JavaScript as well as programming languages like Java or C#.
   A framework for creating Internet and Web applications is provided by QtScript. For enterprise applications, J2EE is used, and for web pages, JSP.
   DotNet offers a platform for creating apps, web applications, and Internet services. For enterprise applications, it uses Visual Studio and ASP.NET, while for web pages, it uses JSP.

2. **Operating System Considerations:** When designing an app, an OS that is compatible with the mobile device is taken into account. The user can launch an application on the iPhone 6. Thanks to iOS 8, which is used by an app designer for an iPhone app. The following are some examples of how an app creator makes advantage of the OS's functions:
   a) Hardware features and specs
   b) Supporting the creation, activation, deletion, suspension, and delay of threads and the scheduling of numerous threads in a system
   c) Interfaces for exchanging information between hardware devices, middleware layers, and application layer software components

d) Facilitating the hardware's ability to run software components
e) Adjusting the device's library settings for the GUI and VUI components
f) Artistic writing, music composition, and graphic design (for example, OS X)

3. **Middleware functions:** Middleware is a term used to describe the computer programmes that connect application components to network-distributed components. Between a user application and an operating system, middleware functions as additional software. Additionally, Mobile OS offers middleware components. The following uses are made of middleware applications:
   a) In order to find adjacent Bluetooth devices
   b) To find the hotspot nearby
   c) To synchronize a device with a server or an enterprise server
   d) To retrieve data from a network database, which may be in Oracle or DB2 format
   e) For transaction processing
   f) To use an application server for a stateless Internet session
   g) For service discovery
   h) For application platform and service availability adaption

4. **Data Synchronization and Dissemination:** A mobile phone can be used as a data access device to access the server of the service provider and retrieve information. Smartphones serve as enterprise data access devices in networks used by businesses. The data is distributed to the enterprise mobile device, such as the BlackBerry handset, by an enterprise server.
   A data access device for accessing music or videos is something like an iPod, iPhone, iPad, or tablet. Files can be downloaded via a link and saved or played afterward. These days, students can record lectures from professors and access e-learning materials using an iPod, iPhone, iPad, or tablet. To communicate, disseminate, or broadcast information, a data dissemination service is necessary. An example of a distribution server for academic lectures, interviews, and learning materials is https://itunes.standford.edu. The same service offers a music, iTunes, and video user interface as well. Media played on iPods is stored on a platform called iTunes, which is a program that can be downloaded from the Internet. At www.apple.com/itunes, Apple distributes music and video content for iPads and iPhones. Application servers, business servers, iTunes servers, and service providers' servers all send data to mobile devices. The three ways for disseminating data are: (i) broadcasting or pushing (such as sending unwanted SMSs to mobile phones), (ii) pulling (such as downloading a ringtone from the mobile service provider), and (iii) a push-pull hybrid.
   Podcasting is a modern type of broadcasting. It is a brand-new technique for sharing multimedia files. For instance, files for music videos and audio programs are disseminated online in formats that can be played on computers and mobile devices. Receiving the multicast or unicast data that is distributed over a mobile network requires

middleware. Additionally, middleware offers data management service transparency and application adaptation. The user does not have to configure the underlying protocols thanks to transparency.

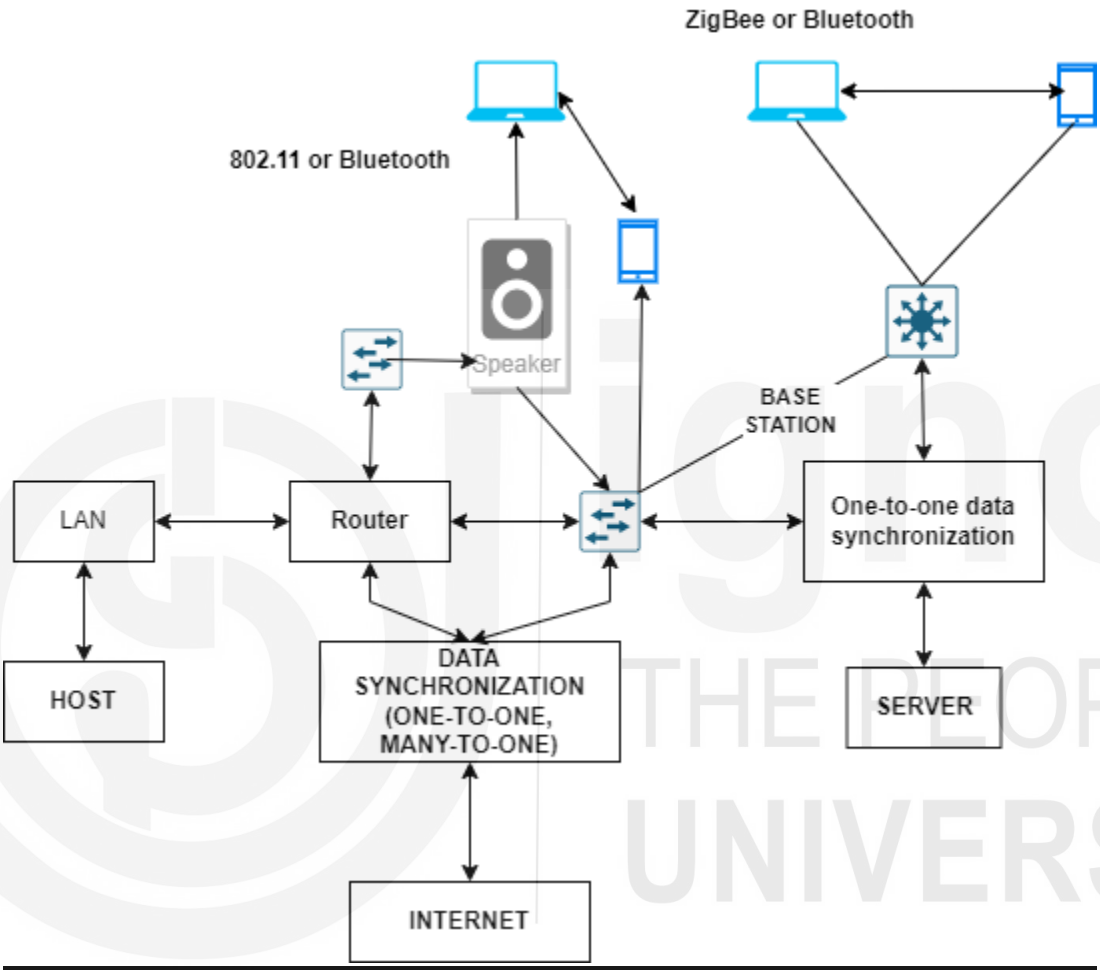


Fig 6: Data synchronization paths

Synchronization

Data synchronization, often known as synchronization, is the process of updating data across many databases so that each repository includes the same data. Data synchronization ensures that all servers of a mobile service provider have the same selection of ringtones if, for instance, a new, well-liked ringtone is added to one of the servers of the service provider. Furthermore, any new data should be made available to all the devices linked to the server. This indicates that a

duplicate of the tone's title can be found in the ringtone database that is accessible to all mobile phones.

One-to-one synchronization: When two ends of a data stream are in sync, every modification made at one end is immediately reflected at the other. The information on the two ends should be the same or consistent. In a data-synchronized enterprise network, the change is reflected at the enterprise servers, for instance, if the address of a mobile device user changes and the user enters the new address in the device's address book. In this situation, a GSM or CDMA network is used to synchronize devices. But when an iPod is put next to a PC and iTunes is downloaded into the PC, the synchronization takes place via Bluetooth or USB connectivity.

A data modification or update at one node or server must be reflected at all other (or target) nodes or servers. This is known as one-to-many synchronization.

Data copies between the server (one) and the nodes should be consistent or identical (many). Inconsistent copies of the same piece of information should not exist on the communicating node or server or on any other node or server.

A modification to data at one node or server must be replicated to all other nodes or servers (the target nodes or servers). Between several nodes, this is referred to as "many-to-many data synchronization." The data should remain consistent or identical across all nodes. There shouldn't be multiple copies of the same data on nodes or servers.

2.8 MOBILE COMPUTING AND THE APPS

The new standard, HTML5, allows for the design of mobile browsers and the creation of mobile applications on the Internet. It also offers additional functionalities.

Utilizing Mobile IP or WAP gateways of direct HTTP applications over 3G data services, users can access the internet for computing. A comprehensive suite called Mobile Enterprise Application Platform (MEAP) is utilized for mobile computing via the Internet. It makes it possible to create mobile applications, which need Web services, servers, and enterprise servers.

A mobile middleware server, application software, and a mobile client API make up a MEAP system. Uses for a middleware server include:

1. Administration of back-end servers' or systems' data
2. Setting up the app for the mobile device
3. System integration
4. Scalability

5. Communications
6. Support across platforms
7. Security

Mobile web applications and modern web applications: HTML5 is utilised for existing applications that are mobile-friendly and relate to web pages and web forms. Numerous capabilities and mobile-friendly controls are available with Microsoft ASP.Net 2.0. ASP.NET MVC tools are used to make the current Web applications mobile-friendly (MVC stands for model, view, and control).

Mobile makes it possible to employ cross-platform development tools, automate testing for tablets, iOS, Android, and Windows 8 devices, and integrate with existing applications as necessary. Analytics can also be used to enhance current apps. (Data analytics refers to the application of methods for drawing inferences following the examination of raw data and the conclusion of the information gathered.)

2.9 NOVEL APPLICATIONS OF MOBILE COMPUTING

There are numerous uses for mobile computer devices. Mobile TV is now a reality because to mobile computing. iPad, tablet, and PCs with extremely high mobility. The size of a paperback book is now the standard for 6" laptops, e-books, and readers.

1. Smartphones

A Smartphone is a mobile phone with added processing capabilities that allow for several applications to be used. For instance, Research in Motion, Inc.'s BlackBerry 8530 curve includes additional computing capabilities that make it possible to use the following applications:

1. Phone, email, address book, MMS (multimedia messaging service), and SMS (short message service). Web surfing, a calendar, a to-do list, and a memo pad.
2. Support for well-liked Personal Information Management (PIM) applications
3. Viewing integrated attachments
4. QWERTY-style keyboard with Sure Type technology (a computer keyboard has keys in order of Q,W,E,R,T,Y,...)
5. Keyboard controls for Send and End
6. Use a headset, vehicle buds, or car kits with Bluetooth to talk hands-free.
7. When EV-DO compatibility is enabled, the device can be used as a wireless modem for a laptop or personal computer.
8. Speaker telephone

9. Polyphonic ringtones allow you to customize your gadget.
10. A vivid, high-resolution display with over 65,000 color options
11. E-Mail
12. 802.11b and 802.11g WiFi
13. Browser
14. GPS tracking
15. Recording and communication through media, including audio, video, and camera images
16. Live TV
17. Micro SD cards

2. SmartWatch and iWatch

The development of mobile computing, NFC, medical device design, smart sensor design, and GPS technology led to the creation of the Galaxy Gear S, an innovative application product that Samsung released in August 2014. It is a brand-new smartwatch. It is a brand-new smartwatch. These are some of its characteristics: It sports a curved 2-inch display. It offers the capacity to make phone calls without using a smartphone at all. It has Bluetooth and Wi-Fi connectivity options. It permits GPS. With its heart rate and UV sensors, it features the S Health app, which alerts the wearer when it's time to eat, when they've had enough activity, and when it's time to relax. It contains walking navigational features. It allows watch owners to send a text message from their wrist. Apple Watch provides apps for those who want to lead an active lifestyle, such as Nike+ Running, which allows users to log morning or evening runs.

3. Music, Video, and e-Books

Apps that let you download music, film, and books are available for tablets and other mobile devices. Reading one's favorite books whenever and wherever one wants is now accessible thanks to tablets.

AAC-LC plays stereo audio in.m4v,.mp3, and .mov file formats at up to 160 kbps and 48 kHz. Apps for tablets and other devices provide mobile TV and MPEG-4 video. E-books can be read as PDFs or PNGs.

4. Mobile Cheque and Mobile Wallet

A mobile-based payment method used when making a purchase is called a "mobile cheque" (m-cheque). The customer, a certain retail location, and the mobile service provider all text messages to activate the service. In order to transfer money to the retailer account, the service provider authenticates the consumer and activates the customer account. The method that payments are made for purchases is changing as a result of these mobile devices. Customers are no longer required to have credit cards in their wallets while they shop.

A mobile wallet is an application where you may access your money via your service provider's account. A bank is used to link the payment when a mobile device connects to the service. Both

the client's and the recipient's bank accounts are connected to the provider.

5. Mobile Commerce

The following is an illustration of mobile commerce (m-commerce). Stock quotes can be accessed on demand or in real time using mobile devices. The stock purchaser or seller first sends an SMS for the trading request, then the stock trading service responds in the same manner, requesting authentication. The client delivers the user ID and password through SMS. The customer is then instructed to continue by way of a confirmation SMS. The client sends an SMS to request a certain stock trade. At the stock exchange terminal, the service provider places the order. Within a couple of minutes, the procedure is finished online.

A buyer communicating their intention to purchase a product to the provider of mobile purchase services via SMS is another example of m-commerce. The service provider sends the product's prices in increasing order of the price at various retailers that sell the same item. Following that, the client asks the service provider to send the order to the least expensive and closest supplier. Additionally, the usage of mobile devices for e-ticketing, or the purchase of movie, train, aero-plane, and bus tickets, is growing.

6. Mobile-based Supply Chain Management

Apps for managing the supply chain on mobile devices effectively manage manufacturing, supply, logistics, warehouse, and other tasks while on the go. The following example provides the clearest explanation of the supply chain management issue. Chocolates cannot be sold by distributors unless they are manufactured. Without a distributor order, the manufacturer cannot produce the chocolates. The supply chain management problem is the name given to this producer-consumer issue. Leading IT firms have created supply chain management system software for mobile devices. Such mobile devices are used by the sales force and the manufacturing facilities to maintain the supply chain.

EXERCISE:

Question 1: Write about the features in a handheld computer.

Question 2: What purposes does data dissemination serve? Why is data distribution required to keep a mobile service running?

Question 3: Describe data synchronization

Question 4: Write short notes on the various cryptographic algorithms.

Question 5: What are the different limitations of using mobile devices?

2.10 SUMMARY

An access point may serve as a bridge connecting wired and wireless networks. It is a system that connects mobile systems and embedded systems to wireless LAN, the Internet, or the network of a mobile service provider.

Base station refers to a transceiver that connects wirelessly to a number of mobile devices or access points and wired or fibre optic connections to mobile switching centres and other networks.

With data rates of up to 1 Mbps, Bluetooth is a standard for object exchange that enables short-range (1 m or 100 m depending on radio spectrum) mobile communication between wireless electronic devices (for instance, between a mobile phone handset and headset for hands-free talking, for connecting the computer or printer, etc.).

By using multiplexing and other approaches, the capacity of the frequency channels—the number of users who can be supported at a particular time—is increased.

A computational structure where a client asks for computations and data, and after the necessary computations, the client receives the needed data or replies It is a computational structure in which, following computations at a server, the client caches or reads the data record(s). Access may occur upon client request, via broadcasts from the server, or via distribution. The client and server may be running on the same computer system or may be running on distinct computers.

Computation carried out on a mobile device while running an application in which a number of servers from a service provider or distributed computing systems take part, connect, and synchronise using mobile communication protocols.

By adopting formats that allow for playback on mobile devices or PCs, multimedia files (such as those for audio programmes or music videos) can be distributed via the Internet using the podcasting technique.

A protocol is a generally accepted recommended procedure for managing and regulating the transmission of data as well as the rules governing the syntax, semantics, and synchronisation of communication between two computing systems. Protocols also establish connections, format and sequence data, address the destination and sources, and terminate connections.

The integration of computations with environment items that have computing capabilities is referred to as ubiquitous computing.

WLAN is a wireless LAN that communicates using sets of common protocols, including IEEE 802.11a, 802.11b, and 802.11g.

Applications for mobile computer systems are numerous. Mobile TV has just lately become a reality thanks to mobile computers. A paperback book-sized version of the ultra-portable PC, tablet, iPad, 6" laptop, e-book, and reader is now available.

2.11 FURTHER READINGS

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MOBILE AND WIRELESS COMMUNICATION

By Leena R. Mehta

Mobile Communication

by: Behera G. K.

UNIT 3 MOBILE CLIENT DEVICES AND PERVASIVE COMPUTING

3.0 INTRODUCTION

The client is a mobile application that queries a server and receives a response. The notifications are also sent by the server. A mobile client is a computer that runs Web applications and functions in a client-server context. Hardware and software are both present in the device.

Modern automation technology makes it feasible to control security systems and household appliances from a computer or mobile device.

Numerous miniature computing systems are included in an automotive computing system. Systems for voice control, traffic congestion information, smartcard-based security control, collision avoidance systems, reverse sensing, night vision, and communication to central real-time traffic monitors are a few examples.

Automotive systems have undergone a transformation during the past 10 years or so. The modern automobiles come equipped with everything from sophisticated information-oriented technology like GPS navigation reverse sensing, and night vision to communication systems like e-mail access, voice control, traffic congestion information, smartcard security control, and collision avoidance sensors.

3.1 OBJECTIVES

At the end of this Unit, you shall be able to:

1. Understand the features and capabilities of mobile music players and smartphones.

2. Understand automotive computing systems.

3. Understand the types and characteristics of mobile devices.

4. Understand about the applications and characteristics of set-top boxes, smartcards, labels, sensors, actuators, and home appliances.

5. Understand the mobile handheld device limitations and design restraints.

3.2 SMART SENSORS, ACTUATORS, AND MOBILE ROBOTIC SYSTEMS

In control systems, sensor-actuator pairs are employed. Like, for instance, a temperature sensor and current actuator pair controls the oven's temperature, a light sensor and bulb current actuator pair regulates the brightness, and a pressure sensor and valve actuator pair regulates pressure.

There are a lot of sensor and actuator pairs in industrial plants. A control area network bus (CAN bus), for instance, is used to connect a group of intelligent sensors and actuators in an automotive or industrial facility.

3.2.1 Smart Sensors

Electronic devices called sensors sense the outside world; examples include sensors for temperature, pressure, light, metal, smoke, and object proximity. The controller or computer receives the signals from the sensor. In order to hear voices, a microphone is used.

A sensor could be a complex system of numerous tiny gadgets. A camera with a charge-coupled device (CCD) base is used to detect and recognize different things. The MP range for cameras is 2 to 12. Signals are produced by each pixel of a CCD. The signals are digitally transformed using Analog-to-digital Converter (ADC).

Mobile devices may interact with their surroundings thanks to their sensors. Here are a few instances:

1. Voice amplification during a call can be managed with the aid of a background noise sensor.

2. The LCD screen's brightness can be managed using a sensor for ambient light. When ambient light levels are very low, it minimizes power dissipation for displays.

3. The amplification of received signals is controlled by a sensor that gauges the signal's strength.

4. Voice is detected by a microphone. A speech processing system receives the voice signals from it (SPS). The SPS verifies the cellphone owner's identity. The SPS can then be used to interpret and carry out spoken commands as well as dial a spoken number.

5. A gyroscope tracks the direction and speed of angular motion along three axes. For recording vibration shocks or falls, an accelerometer detects the device's linear acceleration along three axes. A device's power can be turned on using a proximity sensor.

A tiny magnet hung by a wire forms the basis of a smart magnetometer sensor, which connects to an app for data processing and makes intelligent decisions. It detects and measures the values of three magnetic field strength components in the x, y, and z directions. The meter's tiny magnet points in the direction of the magnetic field's force lines.

The lines of force and the strengths of the magnetic fields in the x, y, and z directions all alter when a magnetized material is present nearby. A small magnet's North and South poles are subject to opposing angular forces. This is as a result of shifting field directions and strengths. The wire develops a torque due to the forces. The small magnet is rotated by the torque that the wire experiences. An app analyses the ensuing modifications and notifies the actions in accordance with the sensor's measured data.

The magnetometer and apps are on the latest generation of mobile devices. An app automatically turns off when the user puts their phone in their pocket and turns on when they hold it in their hand.

Sensors having processors and memory are referred to as smart sensors. They are capable of computing, communication, and networking. They are used to transmit data to a network, a controller, or a central computer. Multiple smart sensors are installed in robotic systems and industrial automation systems.

The processor, memory, ADC, signal-processing component, wireless or infrared receiver, and transmitter make up a smart sensor, which executes both computational and communicational tasks. Assembly language or C language is typically used to programme smart sensors.

3.2.2 Actuators

A controller or central computer sends signals to an actuator, which then uses those signals to

activate a physical system, appliance, or device. A servomotor in a robot's hand, a loudspeaker, a power transistor (used to transmit electricity to an oven), a solenoid-valve actuator, a transmitting device in a sensor network, and other physical devices are examples of this type. The physical system or equipment is activated in response to the commands or signals received from a network, mobile device, computer, or controller via a smart actuator.

3.2.3 Robotic System Sensors and Actuators

The sciences of artificial intelligence and mechanical engineering both contribute to the development of robotic systems in various ways. Robotic systems are essentially programmable machines made up of mechanical actuators and sensory organs connected to a computer inside of them. In industrial robotics, the mechanical structure might include manipulators, but in mobility robotics, it might focus on the robot's movement as a vehicle. The following are a few instances of sensors used in robotic systems:

The left and right foot each have acceleration and force sensors.
The hands and head both include infrared distance sensors.
CCD cameras are located in the eyes.
Angular rate sensor in the centre
ears with microphones
shoulders, hands, and head having thermo and touch sensors

The following are some examples of actuators found in robots:

A robot may have a speaker at its lips so that it can speak spoken commands to other robots or communicate sensed data.

Actuators and motors are present at all joints that move, including the hands, wrist, neck, shoulders, feet, and palms of grippers.

The sensors send signals to the embedded processors at the main computer chip of the robot through internal connections. When a group of robots needs to act in unison, the robot wirelessly transmits data to a central server.

Robots that can move and communicate wirelessly are employed in industrial settings to access spaces that are difficult for people to reach. Robot master-slave systems can serve a number of functions. In such a setup, the master robot issues orders to the other (slave) robots.

Figure 1 below depicts a robot's sensors, actuators, and transceivers. Programming for robot sensors can be done in 'C'language or assembly language.

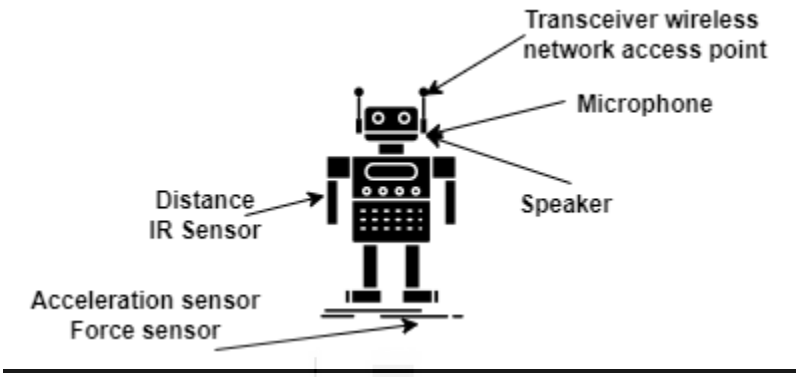

Figure 1

3.3 SMART HOME AND APPLIANCES

Modern automation technology makes it feasible to control security systems and household appliances from a computer or mobile device. Web-enabled gadgets include smart home and workplace products. The following are the networked home devices, a set-top box, and a residential gateway:

3.3.1 Smart Appliances

Using electricity cables, home appliances can be networked. Such wires can induce signals with frequencies as high as 525 kHz. A network can be created by these signals being transmitted from one appliance to another. A central server can be used for the devices to communicate as well. Very short-range wireless protocols like Bluetooth or ZigBee can also be used to network home appliances.

A Web address can be given to a smart appliance. The equipment then utilises a domestic gateway to connect to the Internet. The gateway gives the user access to devices like their home computer, MP3 player, security locks, and other items from the outside via WLAN, the Internet, or a mobile service provider's access point. A network of smart appliances is depicted in Figure.

A domestic gateway is a device that connects your home's electronics to the Internet, including your media player, computer, locks, lights, oven, refrigerator, and air conditioner. The process starts with authentication. The gateway enables access from the outside to the home devices after user authentication.

A service provider server may also be used by the gateway to perform networking tasks.

The mobile service provider may also assign a number to a smart appliance. The SMS service can then be used to control it from a Smartphone. For instance, if a person forgets to turn off a smart air conditioner before leaving the house, it might be turned off by an SMS. Also on the other hand, while returning home, one can turn on the air conditioning by sending an SMS, which will make the room cool before one actually arrives home.

An innovative idea that is currently being developed is electronic appliance maintenance. The appliance can be accessed online by the maintenance service provider, who can then diagnose any problems.

3.3.2 Set-top boxes

A sophisticated computer-based device known as a set-top box connects the home TV to the broadcasting service network. The block diagram of a set-top box's subsystems is shown in Figure 2. There are two sets of communication channels: front and back. This makes interactive TV possible.

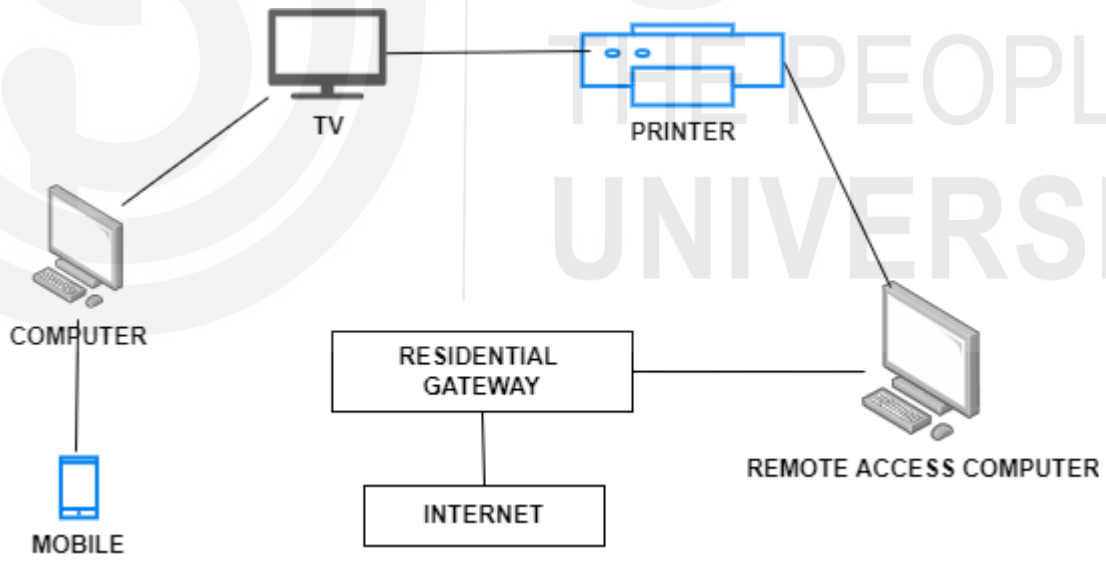

Figure 2

The inputs from satellite dish antennae, cable coaxial lines, phone lines, and wireless antennae are all placed on the front channels. A tuner is connected to the inputs. The front channels' signals are received and decoded by a decoding device. The set-top box decodes the signals it receives from the service provider. Multi-channel tuners are found in set-top boxes. The user-

selected channel is divided by a de-multiplexer. The audio and video are likewise separated. The channel's access requirements are decoded by a decoder.

The gadget has a conditional access system (CAS), which restricts access to TV channels to the window of time set by the channel's service provider. A decoder decodes the signals chosen at the CAS. These are sent to home audio and video systems through the decoder.

Let's use an illustration to demonstrate this. Electricity bills are paid based on how much energy is used in a given month. Similar to this, a set-top box keeps track of the time a channel is utilized, and the service provider bills the user according to the channels and time period they have selected.

Through backchannels, the set-top box transmits its output to wireless antennae, cable coaxial lines, and telephone lines. The outputs moving through backchannels are encrypted using a keying unit. This offers interactive TV, web browsing, and the service provider feedback channels.

The most popular programming language in a set-top box is Java. Software for encryption and decryption is executed on set-top boxes. Device administration is carried out by a software element known as a device agent on behalf of the service provider. This system works in a manner akin to a mobile phone, where the device's management and administration are handled by a server provided by the mobile service provider. Here are a few instances of this:

Similar to a Smartphone, a set-top box can perform a wide range of tasks:

- ✔ Data, media, and network processing are all capabilities of a set-top box.
- ✔ It offers a platform for multimedia games powered by Java.
- ✔ Some set-top boxes have wireless keypads that can be used to control the TV, play video games, browse the Internet, and pick, tune, and modify picture and sound quality.
- ✔ Both a CD-ROM drive and hard discs are present.
- ✔ A USB port can be used to link a set-top box to a computer or printer.

EXERCISE

1. Explain how mobile devices can interact with their surroundings.
2. What are the sub-units in a set-top box?
3. Show the working of sensor-actuator pair.
4. Write a short note on smart appliances.
5. How are sensors used in robotic systems?

3.4 AUTOMOTIVE SYSTEMS

Vehicles/Automobiles today contain sophisticated computational equipment. Since the late 1960s, there has been a significant increase in the usage of computing and processing units in car engines to enhance vehicle stability, transmission and brake functions, and driving comfort and convenience. Automotive systems have undergone a transformation during the past 10 years or so. The modern automobiles come equipped with everything from sophisticated information-oriented technology like GPS navigation, reverse sensing, and night vision to communication systems like e-mail access, voice control, traffic congestion information, smartcard security control, and collision avoidance sensors. A handful of the embedded computing systems found in autos are described in this section. **Figure 3** depicts the mobile computer architecture of a car.

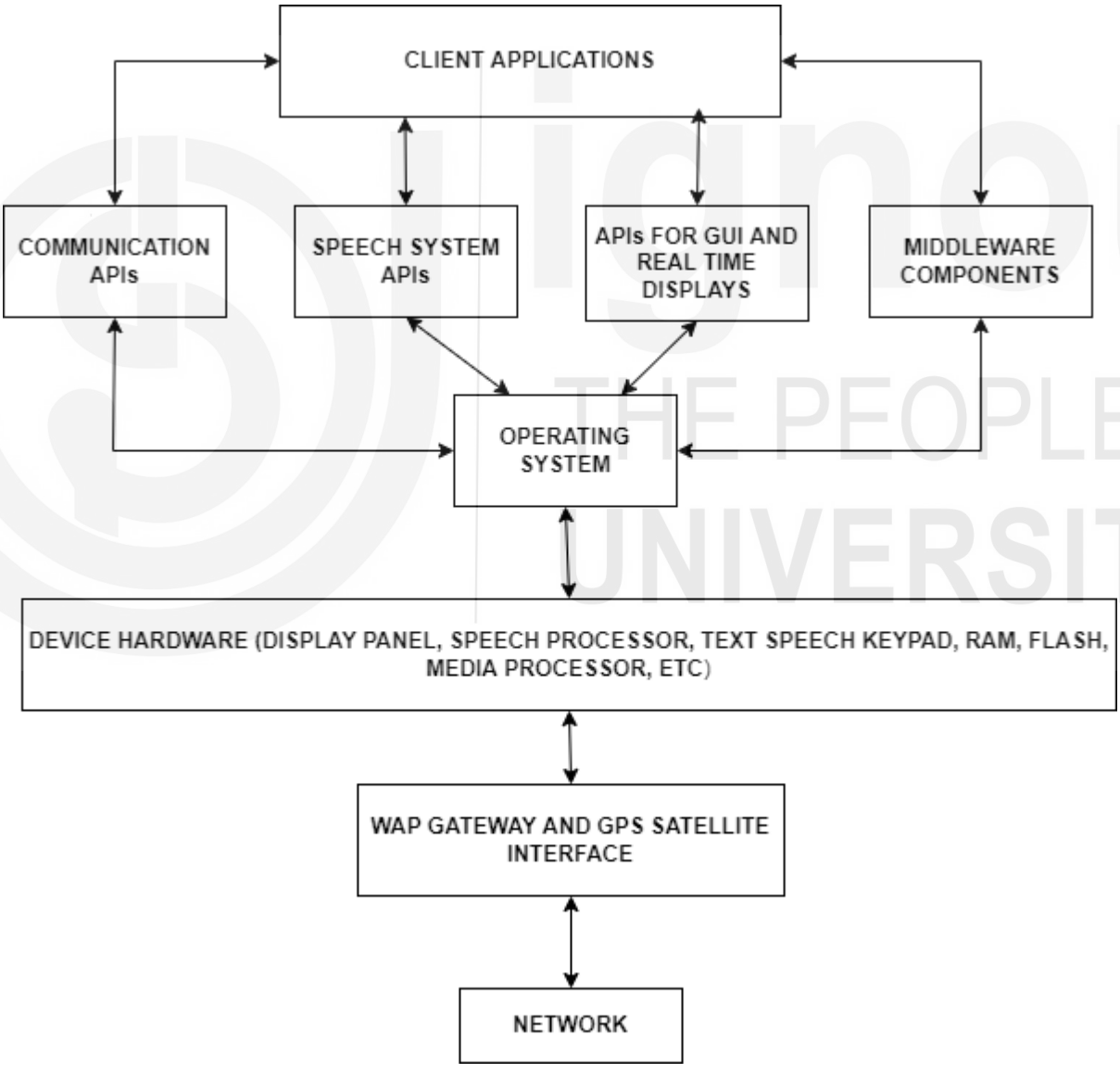

Figure 3

3.4.1 Speech Recognition System

An automobile's speech recognition system (SRS) can be programmed by an application programmer. After the SRS recognizes the voice, the driver can instruct the car to start. Application software can be set up so that the driver can provide instructions to the car to stop, keep going at the current speed, or drive within a set speed restriction. A digital signal processor is used by the SRS.

3.4.2 Messaging System

An automobile's ability to connect to the Internet is made possible by a WAP device. A service provider is able to transmit news, weather information, and stock reports in real time. WAP may be used to get road maps as well. When needed, the maps can be accessed from the memory of a computer that is integrated into a car. The GPS device and a map both aid in navigation.

Traffic reports are sent by a traffic control service. The owner of a car can sign up for a traffic control service that sends an SMS when there are delays or obstructions in traffic at different locations throughout the city. The TTS converter software then turns the messages into speech, which the driver may hear.

It allows the driver to choose routes that will allow for a quicker, obstacle-free travel.

In the event that one car approaches another too closely, an anti-collision system can alert the driver. Using a laser, infrared, or radar technology, it may also detect items that the driver cannot see. Systems that prevent collisions with other objects can also take control of the vehicle.

Application programmers can convert SMS TTS using C in Linux so that drivers don't have to take their eyes off the road to read the text on the display panel and can instead listen to the messages they've received while driving.

Java, Active Server Pages (ASP), and Java Server Pages (JSP) are further tools that programmers can use to create web-based applications and get data from databases at different portals.

An App named 'Flight' is used. As they approach the airport, the driver retrieves flight details from the airline's portal database.

3.4.3 GPS-based Navigation System

A GPS receiver can be installed in a car. It picks up signals sent by numerous GPS satellites that are in circulation around the earth.

The name of the nearby location is determined using the latitude and longitude values. The map of the immediate area is either downloaded instantly or pulled from computer storage. The position is marked on the map, which is displayed on a panel. When the car is moving, the geographic location is continuously marked and altered on a map on a display panel. It aids the

motorist in selecting the proper route that will take them there. The name of the present location and the name of the road being used can also be spoken aloud using data-to-speech converter software.

Application programmers can generate a real-time road map on the display panel in Linux or the Graphic Tool Kit (GTK) language, with the vehicle's location accurately recorded on the map. In the event that the car enters another zone, the real-time API also updates the map displayed on the screen. As the car moves, the API also continuously modifies the designated position.

3.4.4 Automobile Start and Malfunction Logins

To start the car, a smartcard or smart token can be used in its place. In addition to starting the vehicle when put into the host, the card also records data for any problems that occur while driving. The logged data and the specifics of the service history are retrieved from the card at the service workshop using a card reader connected to the computer. With this knowledge, the workshop can provide a better service. The information about the service can then be stored for later use on the card memory by the service provider's computer. The start and malfunction logging application can be created using JavaCard.

3.4.5 Sensor and Actuator Programming

There are numerous sensors and actuators in a car. For instance, warnings about tyre pressure are transmitted through pressure sensors through the display panel. Buses and the ECUs inside the car are used to connect sensors and actuators. A variety of actuators are present in the car, including those for the fuel injector, engine, seat height and angle adjusters, window screen motors, wipers, climate controllers, dashboard display panel, and entertainment systems. The ECUs (embedded systems) inside the car are connected by sensors and actuators. The CAN bus is the interface used by all computing devices.

3.4.6 Entertainment Systems

A variety of entertainment systems can be installed in a car, including FM radios and media players that can play Wave (WAV), RealAudio (RA), and MPEG-1 audio layer 3 (MP3) files. Using a WAP gateway, application developers can create programmes for downloading music from the in formats including WAV, RA, and MP3 You can download files from another system via a USB interface. Smartphone data can be downloaded via a Bluetooth device.

3.4.7 Real-time Applications Programming

An RTOS can be used by a programmer to run real-time applications on a PC connected to a car. Any of the programming languages, including Win32 API, Visual C, and Visual Basic, can be used to create applications. The OS offers APIs for networking, communication protocol, and many threads.

Real-time Java applications can also be developed using OSEK, which stands for "offene systeme und deren schnittstellen fur die elektronik in kraftfahrzeagen" (or "open systems and their interfaces for the electronics in motor vehicles"). Microcontrollers in auto engine control units use OSEK as their operating system.

3.5 LIMITATIONS AND DEVICES DESIGN CONSTRAINTS

Applications for mobile devices must adhere to design restrictions. The following are hand-held mobile device application restrictions and limitations.

3.5.1 Limitations of the Devices

Here are the wireless limitations:

- ✔ Limitations on mobility brought on by the necessity for automatic system configuration, tuning to available wireless networks, location management, network heterogeneity, portability to available band, and spectrum range of wireless medium
- ✔ consistency in bandwidth availability
- ✔ Compared to traditional LANs, wireless network connections have a longer latency interval.
- ✔ environmental barriers and transmission interference
- ✔ Security authentication required
- ✔ Security concerns with GSM, Wi-Fi, MMS, SMS, and other communication channels

3.5.2 Design Constraints for Handheld Mobile Device Applications

A designer must strike a balance between the best user experience, a long battery life, and effective wireless network connectivity. The suggested approach view of the traits typical of mobile handheld devices is presented here below.

Here are the characteristics of handheld devices as design limitations and suggested possible solution strategy.

Hand-held device characteristics as design constraints	Suggestion

A smaller screen size that can only show a certain number of characters	Keep your attention on the user's current task. Use a straightforward layout that enables users to locate what they are looking for quickly and simply, minimises the amount of steps required for users to complete their tasks, and communicates clearly using short, clear commands and labels. Make the user (a) Informed: Make sure frequently used actions and contents, status information, and notifications are obvious and accessed easily. Use concise menus. Use alternatives for less commonly used items. Balance the amount of information on the screen. List items that you use frequently at the top. (b) Confident: The user should be aware of the status of information; for example, a "yes" checkmark indicates that a message was successfully sent. Permitting re-do and undo. Offer many ways to interact with an application. Information that is simple and clear boosts user confidence.
One screen at a time flashes up	Allow users to use the application switcher to switch between programmes. Ensure user comfort by taking the following actions: Make information and screen layouts simple to understand, utilize a minimal list style, and users should find it simple to learn an application. Both expert and unskilled consumers should be catered to in design. Minimize complexity. Make gradual disclosures.

Compared to normal LANs, wireless network connections have a longer time delay.	How quickly users receive information from transmitters over the wireless network can be impacted by longer latency times for wireless network connections. The user experience can be enhanced by using an optimized antenna technology to obtain strong connectivity and quick data transfers, even in places with poor coverage, and caching the data needed later. Software for communication should dynamically adapt to its surroundings, enabling users to stay connected in more locations and focus on what matters to them.
Run down processor speed	Although processor speeds have surpassed 1 GHz, slower processing speeds can still have an impact on how customers feel about the responsiveness of computationally demanding applications like video calling. Applications can manage processor-intensive tasks using background threads.
lower memory storage	The experience that users have with an application is also impacted by memory use. Execute-in-place threads are compatible with flash memory.
Small battery life	The user experience may be impacted by a small battery life. The less frequently a device must activate the wireless connection and the longer the battery life, the more effectively it manages data.

The limitations on design and the suggested strategy are based on BlackBerry's recommendations for application developers, although they work for the majority of devices.

EXERCISE

1. What are the limitations of mobile devices?
2. Write a note about automotive systems.
3. What are the different automotive systems?
4. What are the characteristics of handheld devices?

3.6 SUMMARY

A physical equipment, appliance, or system is activated by an actuator, a device that responds to signals from a controller or central computer. A computer may or may not be built inside an actuator. The GPS satellite constellation is used to synchronize GPS trackers, which are distributed computing systems, all across the world. It is a navigational aid that is necessary. There are numerous places on the planet where GPS satellites have been positioned in orbit. Devices equipped with GPS tracker (receivers) can pick up satellite signals and decode the delivered data to read time stamps. The receiver determines the precise geographic position by using delays of the stamped time in signals obtained from the satellites. A sensor is a device that perceives the physical environment, such as proximity to an object, temperature, pressure, light, metal, and smoke. It can be connected to a controller or computer. A computer for wireless communication could be embedded in a sensor. A complex computer-based device with the ability to process data, media, and networks is referred to as a set-top box. It utilizes Java as the programming language and connects the broadcasting service network and the home TV.

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UNIT 4 GSM AND GPRS

4.0 INTRODUCTION

In 1993, the second-generation (2G) mobile communication architecture was unveiled. Compared to the first generation, it includes a lot of new features. Services like text messaging, multimedia messaging, data communication, and Internet access are made possible by it.

One of the most widely used mobile communication standards is the worldwide system for mobile communications (GSM). It covers more than 200 nations and territories and holds a market share of more than 90% in wireless communication.

GSM was created to provide hand-held devices, international roaming, good speech quality, spectral efficiency, interoperability with integrated services for digital networks (ISDN), and inexpensive service costs. Cellular networks are used for GSM communication.

4.1 OBJECTIVES

After going through this Unit, the learner shall be able to:

- Understand the global system for mobile communications (GSM) and services
- Understand the architecture of GPRS and comparable systems.
- Understand the services offered using GSM
- Understand GSM network operation and maintenance subsystems that include radio, network, and switching services in their GSM architecture.
- Understand Public Land Mobile Network (PLMN) and GSM radio interface
- Understand Addresses, IDs, and protocols for GSM subscribers

- Understand Mobility management procedures: location, calling, and handover
- Understand Safety in the GSM network
- Understand SMS introduction
- Understand GSM Architecture
- Understand GSM architecture in mobile computing

4.2 GSM ARCHITECTURE

Global System for Mobile Communication or GSM is a cellular technology that is open and digital and is used for mobile communication. It utilizes the 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz frequency bands across 4 distinct bands. It uses both FDMA and TDMA simultaneously. The entire GSM architecture and operation are covered in this section of the Unit.

There are four different cell sizes used in GSM:

1. Macro: The base station antenna is installed in this size of cell.

2. Micro: The antenna height in a cell of this size is lower than the typical roof line.

3. Pico: A few metres in diameter for small cells.

4. Umbrella: Covers the shadowed areas by filling in the spaces between the cells.

GSM's features include:

- ✓ Enables international roaming facility
- ✓ Supports Voice clarity
- ✓ Flexibility to accommodate a variety of portable devices.
- ✓ Efficiency of spectrum and frequency
- ✓ Small, portable gadgets.
- ✓ Network compatibility with international ISDN with ease of access.

GSM is nothing more than a larger system that is further broken down into three subsystems.

1. Radio Sub System (RSS)

2. Network-switching sub system (NSS)

3. Operation support subsystem (OSS)

RSS is made up of the base station controller (BSC) and mobile station (MS). For the RSS, NSS, and OSS subsystems, there are three sets of interfaces. The network architecture of the GSM system, as well as the networked and network entities BSC, MSC, GMSC, OMC, and EIR in RSS, NSS, and OSS, are shown in Figure 1. The various components of a GSM network's detailed design and their functions are as follows:

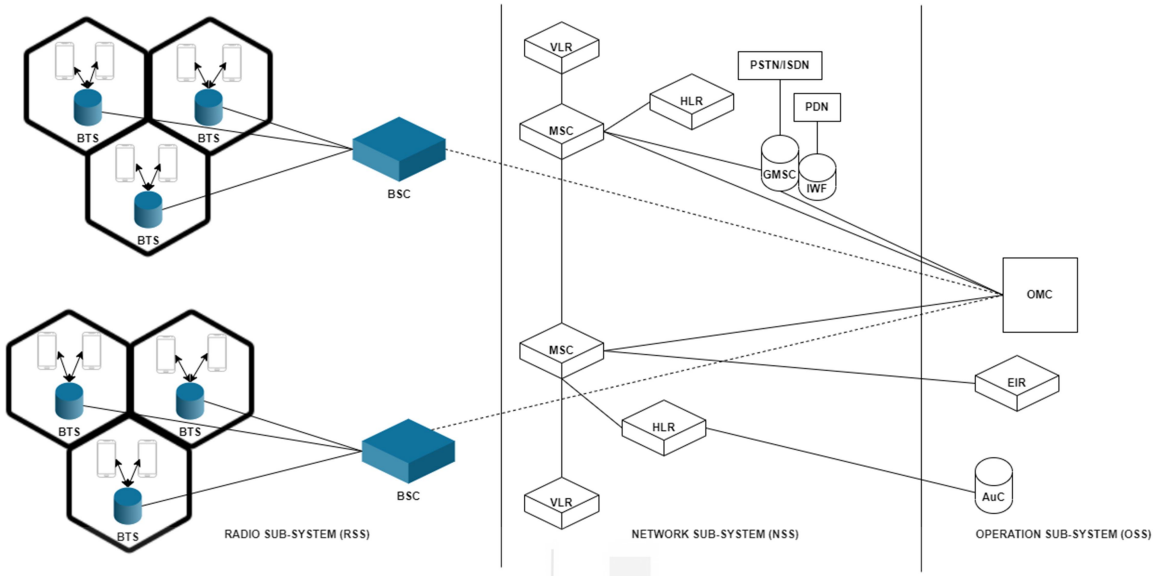


Figure 1

4.2.1 Radio sub-system (RSS)

All radio-specific components of the GSM network are included in the radio sub-system (RSS). The fundamental tasks of connecting the mobile station (mobile device or phone) to the network are carried out by RSS. It includes a number of base transceiver stations (BTSs), mobile stations (MSs), and base station controllers (BSCs). Each BSC links to a number of BTSs, which in turn give a number of mobile stations radio interfaces.

Mobile Station

A mobile terminal (MT), terminal equipment (TE), and a subscriber identity module (SIM) card make up a mobile station (MS).

Radio Interfaces

Base Transceiver station. A BTS serves as the mobile stations' interface. A cell can be uniquely identified by it. To put it another way, every cell has a separate BTS. Through an interface, a connection is made between each MS and the BTS (see Figure. 1). A radio interface, commonly referred to as an air interface is U_m. The BTS is equipped with equipment for encryption and decryption as well as transceivers and antennas for sending and receiving electrical signals. The size of the cell is determined by its transmitting power, which is often positioned near the cell's centre.

The following are the primary functions carried out by the BTS:

1. *Cell formation with antennae pointed in the right directions.*

   Typically, one cell in the GSM cellular network is managed by a BTS. A single BTS can also be utilized to control numerous cells when cells are segmented into various sectors and a directed antenna is used for each sector.

A sector is a geographic area that is enclosed by a circular arc that has all of its points inside a solid angle of 30°, 45°, or 60°. For instance, 12 sector antennae with radiation patterns aimed at solid angles of 30° from one another can manage 12 cells and cover all directions from the BTS.

2. *Signal processing*

   Signals are amplified to a manageable level so they can be sent without data loss.

3. *Decoding and encoding of channels* (e.g., coding voice into bits so that it can be transmitted at 13 kbps and decoding received coded signals back to voice).

   Voice traffic is handled by BTS at varied rates (full rate 13 kbps, other rates 5.8 kbps, and enhanced 5.8 kbps to 11.4 kbps, and additional enhancement to 22.8 kbps). BTS employs varying data rates based on the volume of traffic.

4. *Frequency hopping* enables the operation of numerous channels for distinct mobile stations at once using varied channel band frequencies.
5. *Data encryption and decryption*.
6. Getting used to the speed of data (e.g., The receiver clock of the transceiver at one end of an interface adjusts itself in synchronous data transmission in accordance with the transmitter clock of the transceiver at the other end.).

7. Paging an MS.

   One-to-one communication between a BTS and an MS is referred to as paging. Paging channel is a channel that is set up by each cellular broadcast station.)

Base station controller.

Multiple BTSs are managed by a BSC. It connects to BTSs via a different radio interface called the A_{bis} interface (see Figure 1). The handovers between BTSs are managed by BSCs, which also reserve radio frequencies for communication. When an MS moves, service is switched from one cell BTS to the following cell BTS. A base station system (BSS) is made up of a BSC, together with any BTSs connected to it and any mobile stations maintained by it, as depicted in Figure 1.

In the network switching subsystem (NSS), a BSC is also linked to an MSC through interface A. (see Figure 1)

In the network switching subsystem (NSS), a BSC is also linked to an MSC through interface A. (see Figure 1)

Within a BSS, directing signals to connected BTSs and managing the handover of one BTS to another (see Figure. 1). Control of and signal transfer from BSC to MSC. Using an interface, a channel's signals are mapped between the BTS and the BSC.

The following are some of the key tasks carried out by the BSC:

- ✓ signal processing.
- ✓ managing the transmission of signals to the connected BTSs and the transfer of signals from one connected BTS to another inside a BSS. (Refer Figure 1)
- ✓ Controlling and handover of the signals from BSC to MSC.
- ✓ Using interfaces, a channel's signals are mapped between BTS and BSC and between BTS and MSC. When interacting between BTS and BSC or BSC and MSC, each channel of traffic data and control data needs to be mapped to the interfacing signals. Signals from the BTS are received by a BSC at a specific time at 16 kbps through A_{bis}, and they are interfaced to an MSC at 16 kbps (see Figure 1). As an alternative, it might need to connect over a fixed line network at 64 kbps to a PSTN switching centre.
- ✓ The term "mapping" in this context refers to the assignment of a 16 kbps BTS signal to a 64 kbps signal in such a way that each traffic data channel in the BTS signals can be shifted to the proper channel at the receiver end and vice versa.
- ✓ Reserving radio frequency.
- ✓ Setting aside radio frequencies. 124 frequency channels make up GSM 900 MHz. Each channel employs TDMA to carry MSS traffic. For BTS-MS connection, a maximum of 90 channels may be used at once. 32 channels are designated for management and control data chores.
- ✓ Frequency hopping enables the use of several channel bands by numerous BTSs operating in one go.
- ✓ Continual monitoring of the frequency channel spectrum in use at any one time is employed to regulate traffic.
- ✓ Data authentication, data encryption, and data decryption.
- ✓ Updating the MS location register. (Each subscriber's mobility needs to be watched for the transmission of calls coming from other cells or distant networks. Each MS position, as determined by the signals from the BTS, is communicated by BSC to MSC. Using the signals from the BSC, MSC updates the subscriber's location register.)
- ✓ Paging to a BTS.

4.2.2 Network Switching Sub-system

A variety of MSCs make up the NSS. A number of BSCs in the RSS are interfaced with by each MSC of the NSS. A Home Location Register (HLR) and a Visitor Location Register(VLR) are also available at the MSC. Later on, we'll talk about HLR and VLR. To facilitate switching for communication to the opposite end network, the NSS essentially serves as an interface between fixed and wireless networks. Mostly switches and databases make up this system. It oversees operations including handovers between BSSs, global user localization, user account maintenance, call costs, and roaming service management.

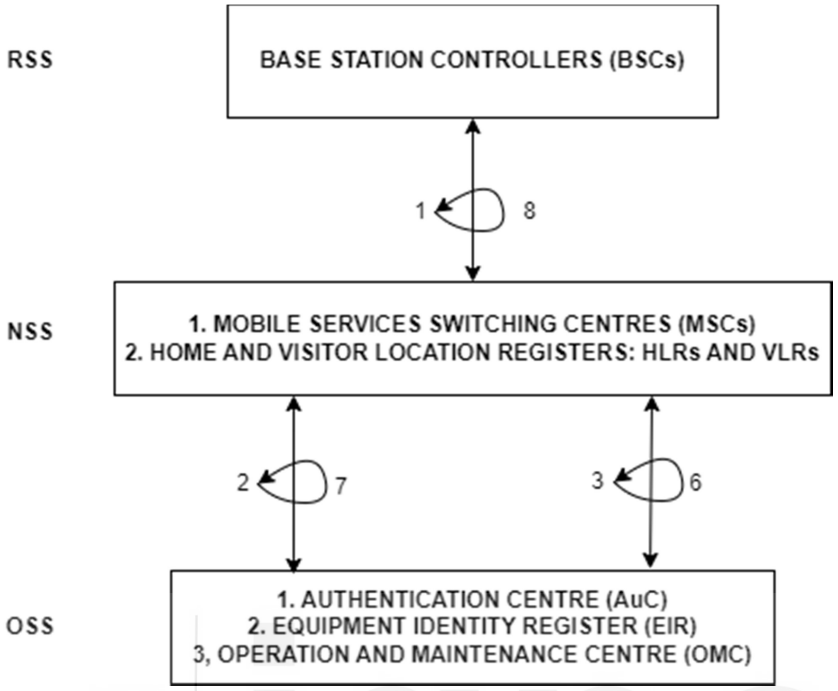


Figure 2

Figure 2 above depicts the NSS's architecture as well as its interfaces.

The NSS's fundamental linkages and components can be summed up as follows:

Multiple BSSs can be managed by each MSC in the NSS.

HLR and VLR are present in every MSC. The HLR communicates with an OSS authentication centre (AuC).

Through the gateway MSC, an MSC can connect to another MSC or fixed line networks (GMSC). Gateway refers to computer hardware and software used for protocol and data conversion during communication between two distinct network formats.

A GMSC consists of cooperating functions (IWFs). The data communicated through the air interface is converted, encoded, and decoded by the IWF software and hardware. The data is transmitted using a format and protocol that are appropriate for PSTN, ISDN, and PDN connections as well as public and private data networks. When an MSC interacts with different types of networks, such as the PSTN, IWF refers to interfacing capabilities in a PLMN and MSC that conduct protocol conversions and adjust to data rates.

An OSS operation and maintenance centre (OMC) is connected to a GMSC (Figure 1). Additionally, GMSCs are utilized to establish connections to the NSS's PSTN, ISDN, or packet-switched public data network (PSPDN).

When one mobile station MS_x and another mobile station MS_y interact, the MSC creates (switches) a link (channel) between the following mobile stations: (i) MS_x, interacted with the BTS, then the BSC, and finally the MSC. (ii) MS_y, interfaced with the BTS, BSC, and finally MSC. A radio sub-system is provided for the communication by the RSS and NSS. To enable the NSS to find a path (route or channel) between MS_x and MS_y, the MSC must include location registers.

Mobile Switching Centre

High-performance ISDN switches make up the majority of an MSC. Through the A interface, it communicates with several BSCs. The BSCs in a specific area are managed by an MSC. An MSC carries out the following tasks among others:

- Signal processing
- Using BSCs to establish and break connections between different mobile stations. The communication path must go through another MSC if the mobile stations to be connected are located in another MSC's territory or in the territory that belongs to that MSC.
- Establishing and disabling a connection over the IWF between an MS and a fixed-line phone.
- Calls made to and from an MS are being tracked.
- Call forwarding, call charging, and other supplemental services are available.

Home Location Register.

The MS databases in a GSM network are stored in the HLR. It keeps track of all pertinent subscriber information, including the mobile subscriber ISDN number (MSISDN number), information on subscription privileges such call forwarding and roaming, the international mobile subscriber identity (IMSI), the user's current VLR, and MSC status.

Globally, each mobile user has a single, real-time, continuously updated HLR record. Each MS is required to register with a particular HLR of a particular MSC. For authentication, the HLR gets in touch with AuC in the OSS. Each HLR is linked to an MSC, enabling the home MSC to update the user's current VLR whenever the MS registered at a given HLR moves to a different location area (LA) served by a different MSC.A mobile station's location is updated with the aid of HLRs.

Gateway Mobile Switching Centre

A gateway is a node that connects two distinct network types. A node of the GMSC is in charge of connecting to other fixed-line networks. These additional networks could be PLMN, ISDN, PSTN, or PSPDN.

A GMSC might use interworking functions special (IWF) like the X.25 to connect to open data networks.

4.2.3 Operation Support Sub-system

The MSCs' operations are made easier by the operation support sub-system (OSS). The entire network's management, upkeep, and operation are handled by the OSS. It is

made up of an operation and maintenance centre (OMC) , an equipment identity register (EIR), and an authentication centre (AuC). The OSS architecture and interfaces to NSS and RSS are shown in Figure. 2. Each AuC in the NSS has a connection to an HLR, and each EIR has a connection to an MSC. An OMC in the OSS can link to a BSC in the RSS, an MSC or GMSC in the NSS.

Through the interfaces, an OMC monitors and manages all other network elements. The management of status reporting, traffic monitoring, subscriber security management, and accounting and billing are examples of common OMC duties.

Authentication Centre

The HLR employs an AuC to validate user identity. The HLR itself may additionally contain a secured partitioned portion called the AuC. The GSM standard stipulates that the methods for key generation should be segregated out as an OSS network unit because mobile networks are very susceptible to attacks. It is called the AuC. Keys for subscriber authentication are kept in the AuC database. The AuC also performs other functions like calculating authentication parameters. The HLR receives these from the AuC after that.

Equipment Identity Register

International mobile equipment identity (IMEI) numbers are kept in the EIR for the entire network. In order to locate a lost or stolen device, the network can use the IMEI to identify the type of terminal, mobile equipment maker, and model. There are three different sorts of lists in the EIR:

- Mobile stations that have been reported as stolen or are currently locked for whatever reason are included on a black list.
- A white list that keeps track of all active and legitimate MSs.
- A grey list of all the MSs that might not be operating properly

4.3 PUBLIC LAND MOBILE NETWORK (PLMN) INTERFACE

A network known as the Public Land Mobile Network (PLMN) was created and managed by a reputable operating agency with the specific objective of facilitating mobile telecommunication services on land for the general public. There is a unique PLMN for each mobile service provider. Any PLMN can be identified by both its mobile network code (MNC) and mobile country code (MCC). For data exchange, PLMN is linked to other PLMNs, PSTNs, or Internet service providers.

4.3.1 Interfaces for the Services

Interface refers to a radio interface, which is communication hardware and software that transmits and receives radio signals. Radio refers to the transmission and reception of radiation. A communication system may also include an antenna.

What If a mobile station, MS, is located at a mobile terminal, MT? In order to be sent, voice and data signals from the terminal are encoded by the MT, a sub-unit.

Additionally, in order for the user at the terminal to understand the received signals, the MT decodes them back into voice or data.

A communication network (such as a GSM PLM) and another terminal, TE, are connected through the MT. Callers connect and communicate via the TE. The TE is the source or destination of the service, and the MT is in charge of mobile communication.

As seen in Figure 3, a caller TE transmits data over interface 1 and interface 2 to a PLMN, interface 3 to a source-destination network, and interface 4 to a terminal or mobile station TE. (An ISDN or PSPDN network may be used in place of the PSTN network depicted in the figure.)

The linked TE then transmits data back through interfaces 5, 6, 7, and 8. (1,8), (2,7), (3,6), and (4,5) are four different interface sets. Each set has a transceiver. A transceiver is a group of interfaces (transmitter cum receiver). It is customary to use the sign U_m (user mobile interface). The interface is indicated (1,8). It is customary to use the letter A. It designates a mobile network interface (2,7) to a wired network, such as the PSTN or other wired network.

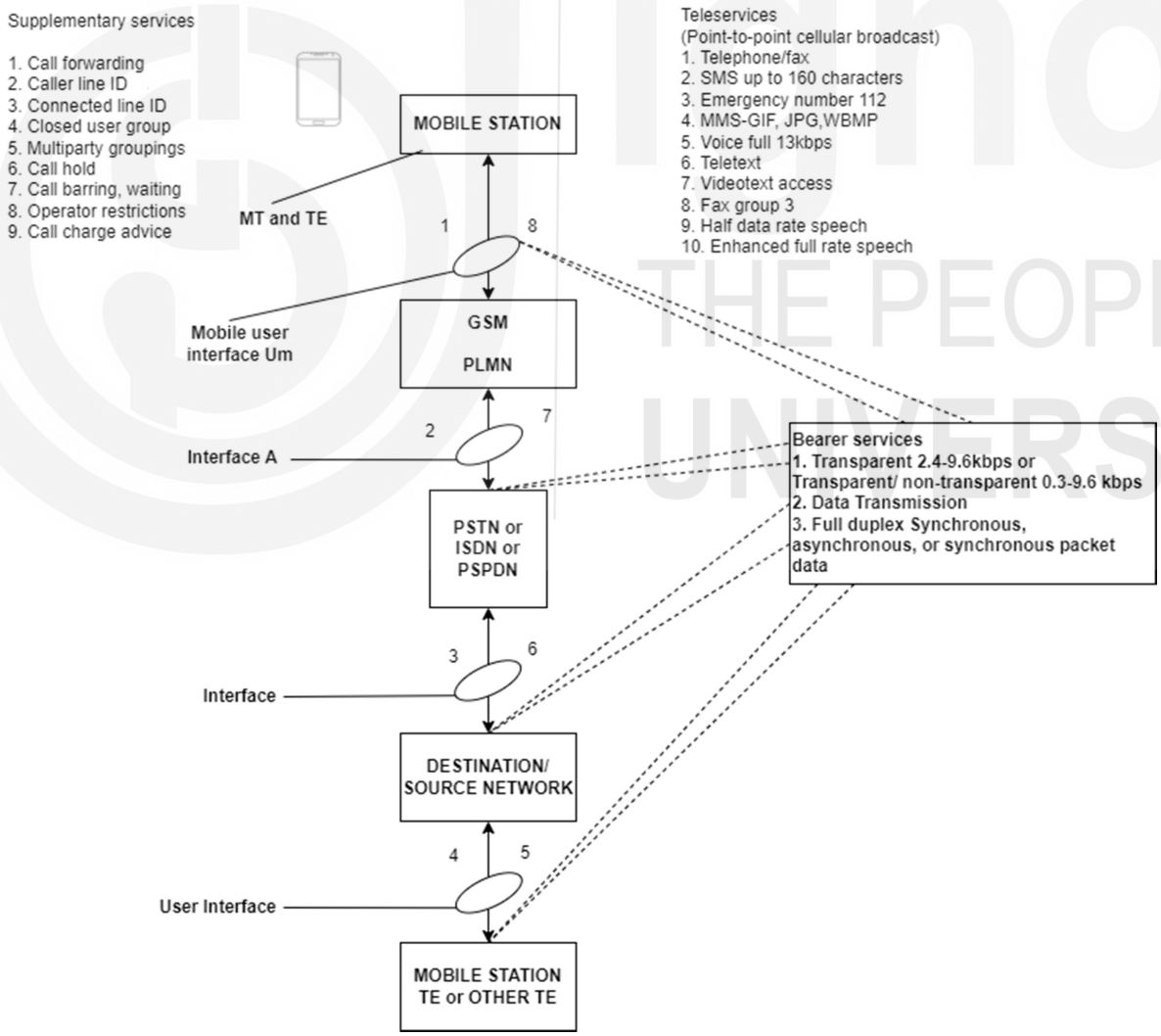


Figure 3

Each of the four transceivers can operate in full duplex mode for both transmitting and receiving (shown by the up and down arrows in Figure 4)

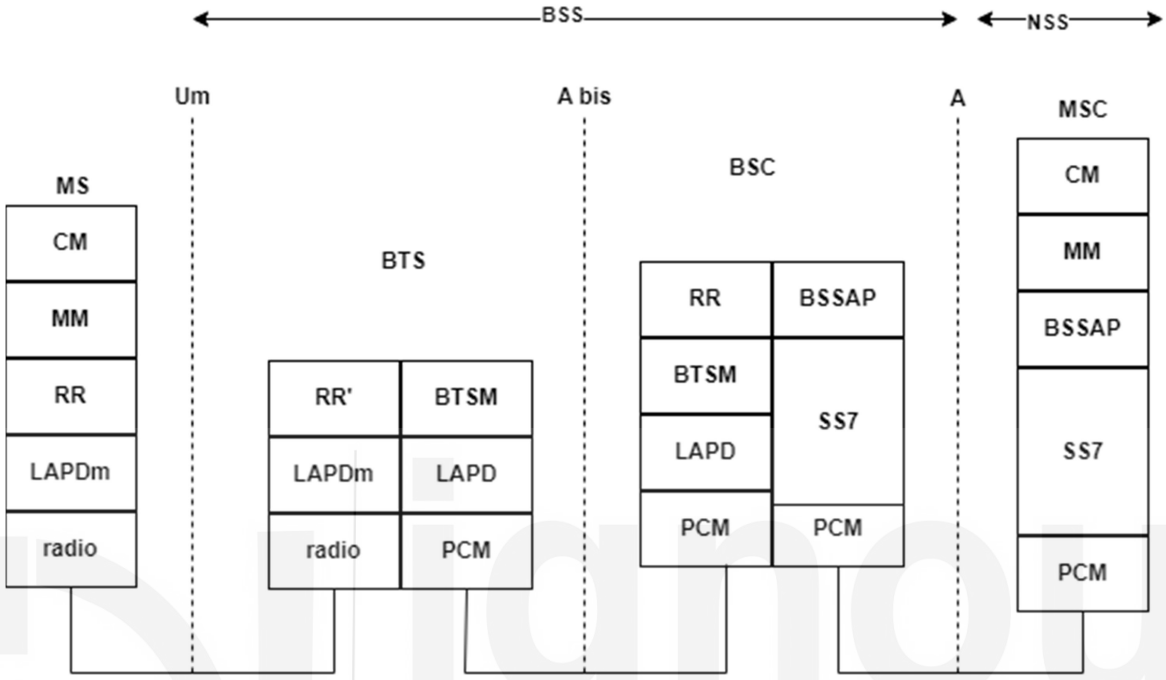


Figure 4

Two-way transmission occurs simultaneously in full duplex mode. Half-duplex transmission is another option for the MT interface. Half-duplex refers to the ability to transmit in both directions but not simultaneously. Here are a few instances of how to create a connection in a GSM network:

- ✓ A GSM mobile phone and a PSTN phone can communicate (old landline phone). A mobile station at the caller's end connects to the GSM landline mobile network in this instance using an U_m user interface. The landline phone TE, which connects via a source-destination network, serves as both the caller's final destination and the source of the response (PSTN in this case).

- ✓ It is possible to connect two GSM mobile phones. A mobile station TE at the caller's end connects to a GSM public landline or mobile network in this scenario. Another mobile station TE serves as the call's destination and the source of the response, bridging the source-destination (a GSM public land mobile network in this case).

- ✓ A GSM phone can be linked to a landline. The caller's end source TE connects to the PSTN network. A mobile station TE that connects to a GSM public land network in this instance serves as both the call's destination and the source of the reply.

4.4 CALL HANDLING

Figure 5 depicted communication between two TEs from mobile stations. A mobile station TE or other TE could make up the other TE (such as a PSTN phone). According to Figure 5, the calling TE was an MS connecting to the other TE over the path 1-2-3-4-5-6-7-8.

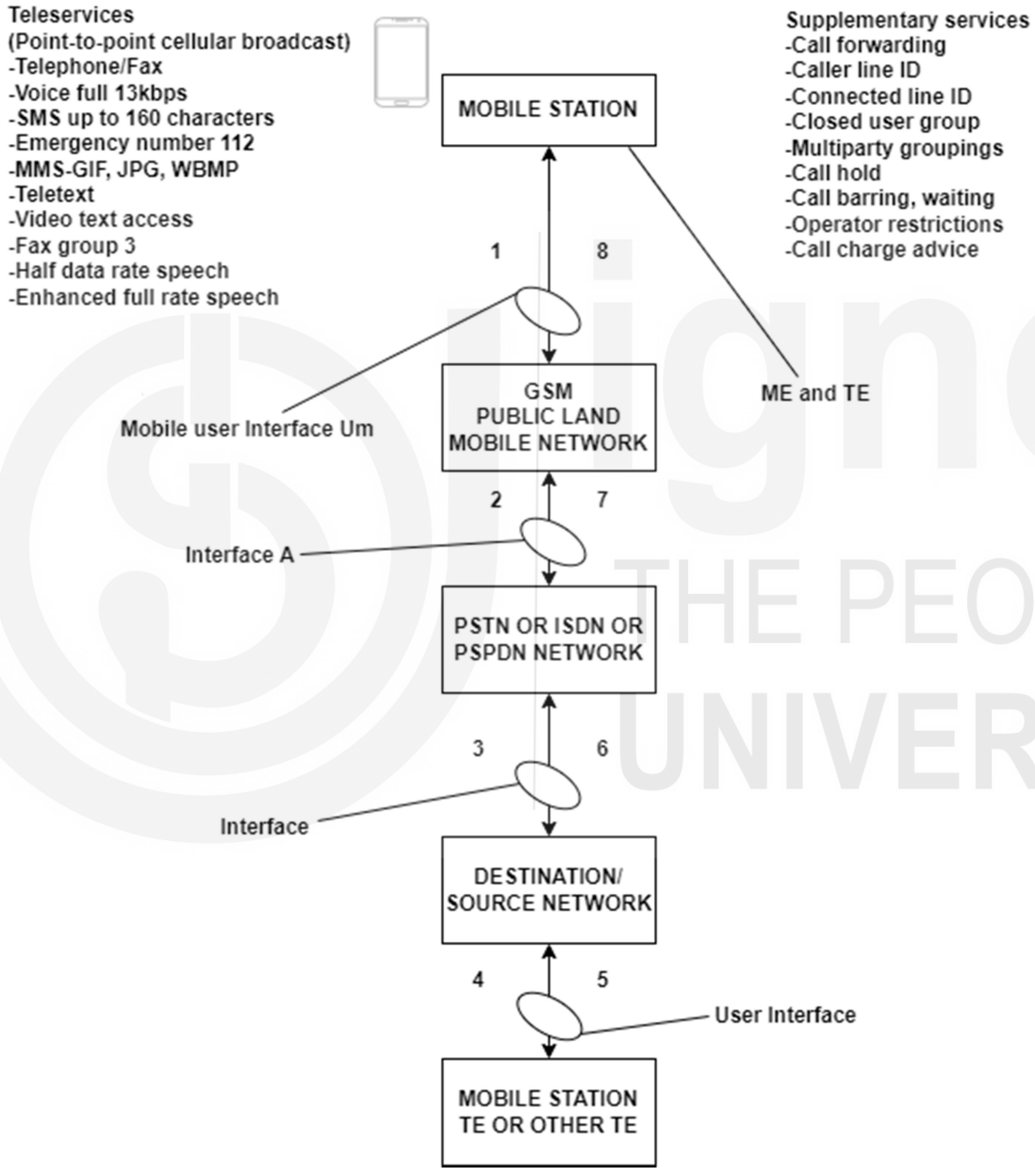


Figure 5,

A PSTN phone may also be the caller's TE. In a GSM PLMN network, calling to and from mobile devices employs a variety of connection-establishing and

communication-maintaining procedures. A GSM network can handle several different call types, including calls from a mobile TE to a PSTN destination TE (**Mobile→PSTN calls**), calls from a mobile TE to a mobile destination TE (**Mobile→Mobile calls**), calls from a PSTN destination TE to a mobile destination TE (**PSTN→Mobile calls**), and exchange of messages between the mobile station and the base transceiver (**Mobile station →Base transceiver message exchanges**). The following are the different call types and the associated procedures:

Mobile→PSTN Calls

Calls that start at a mobile terminal and terminate at a PSTN destination are referred to as PSTN calls. To further understand how the call's connection is made and maintained, let's use an example. Switching centres MSC_i and MSC_j establish the link when a mobile station, MS_i, dials a PSTN number and connects with it. In order to connect MS_i and TE_j, MS_i establishes (switches) a channel in the way described below:

- ✓ According to Figure 1, MS_i connects to BTS_i, BSC_i, and MSC_i via interface routes U_m, A_{bis}, and A.
- ✓ Using the VLR, MSC_i authenticates and verifies MS_i. Additionally, it finds the MSC_j and $GMSC_j$ routes that lead to the PSTN phone TE_j.
- ✓ MSC_i changes to MSC_j, followed by $GMSC_j$, and finally TE_j.
- ✓ TE_j sends back to $GMSC_j$ and MSC_j.
- ✓ MSC_i transmits back to BSC_i, BTS_i, and MS_i after switching from MSC_j to MSC_i.

Mobile→Mobile Calls

Calls that start from a mobile terminal and terminate at another mobile terminal are referred to as mobile calls. To further understand how the connection is made and maintained during such a call, let's use an example. Switching centres MSC_i and MSC_j are used to route communication when a mobile terminal MS_i calls and speaks with another mobile device MS_j. In order to establish a link (channel) between MS_i and MS_j, MS_i does as follows:

- ✓ As indicated in Figure 1, MS_i connects to BTS_i, BSC_i, and MSC_i via interface routes U_m, A_{bis}, and A.
- ✓ Using the VLR, MSC_i authenticates and verifies MS_i. Additionally, it finds the MSC_j-based routes that go to the mobile phone MS_j.
- ✓ MSC_i transitions to MSC_j and uses the VLR to verify and authenticate MSC_j.
- ✓ BSC_j, BTS_j, and MS_j are connected to through MSC_j.
- ✓ MS_j then transmits back to MSC_j.
- ✓ Switching from MSC_j to MSC_i, which then transmits to BSC_i, BTS_i, and MS_i.

PSTN→ Mobile Calls

Calls from the PSTN to mobile destinations via the GMSC are referred to as PSTN → Mobile calls. For instance, while placing a call to a mobile terminal MS_j, a PSTN terminal TE_i connects to GMSC, which then asks HLR to find MSC_j. After authenticating and verifying MS_j using VLR_j, MSC_j routes the call to MS_j via BSC_j and BTS_j.

Before any speech or data exchange through the base transceiver can start if a mobile station MS_i is establishing up a call to another terminal TE_j, the following message sequences must be exchanged between BTS and MS_i:

- ✓ When the MS asks the BTS to give it a channel for communication, the BTS reacts right away by giving the MS a channel.
- ✓ After receiving a service request from the MS, the BTS responds by asking the MS to authenticate.
- ✓ The BTS transmits a command (with a ciphering number) for ciphering at the MS along with its response for authenticating the MS. Using a random number sent by the AuC and a cypher key accessible at the BTS for accessing the MS, a ciphering number is created.
- ✓ The MS applies an algorithm to the BTS's ciphering number and the SIM's cypher key. A key for encryption is created by this algorithm. When the mathematical method is finished, the MS sends the data to the BTS. The MS does not send the produced encryption key to the BTS; just the message of algorithm completion is. To obtain this key for decrypting the encrypted communication entering from the MS, the BTS must separately run the algorithm.
- ✓ The MS and BTS configure the call using the call management (CM) and BTS management (BTSM) protocols, respectively.
- ✓ The BTS informs the MS that the call is set up.
- ✓ The BTS communicates assignment commands to the MS, and the MS communicates assignment completion notifications to the BTS.
- ✓ Before the connection, a warning message is transmitted from the BTS to the MS.
- ✓ From the BTS to the MS, a message for connection establishment is sent, and from the MS to the BTS, a message for connection acknowledgement.
- ✓ The exchange of voice or data begins.

The base transceiver BTS and mobile station MS exchange the following messages before the voice or data exchange starts when a mobile station MS_i, (bottom TE in Figure 4), is getting ready for a call from another terminal TE_j, (top TE in Figure 4).

- ✓ The MS asks paging from the BTS, and the BTS responds with a request for channel assignment.
- ✓ The BTS assigns the MS a channel right away, and the MS responds to the BTS's page.
- ✓ The BTS sends an authentication request to the MS, and the MS replies with an authentication answer to the BTS.
- ✓ The MS receives a ciphering order from the BTS, and the BTS receives a ciphering completion message from the MS in response.
- ✓ The call is established using the CM protocol at the MS and the BTSM protocol at the BTS, and the MS notifies the BTS that the call has been established.

- ✓ The BTS communicates assignment commands to the MS, and the MS communicates assignment completion notifications to the BTS.
- ✓ The BTS notifies the MS of an alarm prior to the connection being made.
- ✓ The BTS notifies the MS that a connection has been established, and the MS notifies the BTS of the establishment of the connection.
- ✓ Data or voice exchange starts.

Exercises

1. What services are offered by a GSM system? What are the steps for connecting to and communicating with another mobile station? How would connecting a mobile station to a PSTN destination affect the in-between interfaces?

2. Describe the various GSM system architecture sub-systems and units.

3. How can a single base transceiver in a GSM system connect to several mobile stations?

4. How does a mobile station access the frequency channels and time slots?

5. Describe the traffic on TCH/HS11.4, TCH/13.4, TC F14.4, TCH/F9.6, and TCH/F4.8.

6. Explain how does an SMS message transfer occur? Describe the interfaces needed for the SM MT and SM MO and display the SMS architecture.

7. How does a mobile station become localized in a new location?

8. How are the RSS and NSS units and interfaces used by the various call types (mobile-originated calls to PSTN destinations, mobile-originated calls to mobile, and mobile-originated PSTN calls)?

9. Describe the communication between the base transceiver and the mobile station.

4.5 HANDOVER

A process for handing over control of a mobile device to a neighbouring cell is referred to as handover. It is sometimes called handoff, as handover to one is handoff from another. However, this portrayal of the handoff/handover process is overly simplified. Technically speaking, handover refers to the process of moving an active call (or data transfer) to a different channel. The call may be transferred entirely to a different network via the core network or transferred at different layers of the system architecture.

In cellular networks, handover typically occurs for one of two reasons:

(i) If the mobile device moves out of one cell's (base station) coverage area and another base station can give it a stronger signal, as well as

(ii) if all the channels of one base station are in use, another base station nearby may be able to serve the device.

Every cellular network must have a handover procedure. Additionally, the handover process must be performed quickly and without causing the user any inconvenience. Different networks employ various handover methods.

The RSS and NSS units are seen completing handovers in Figure 6.

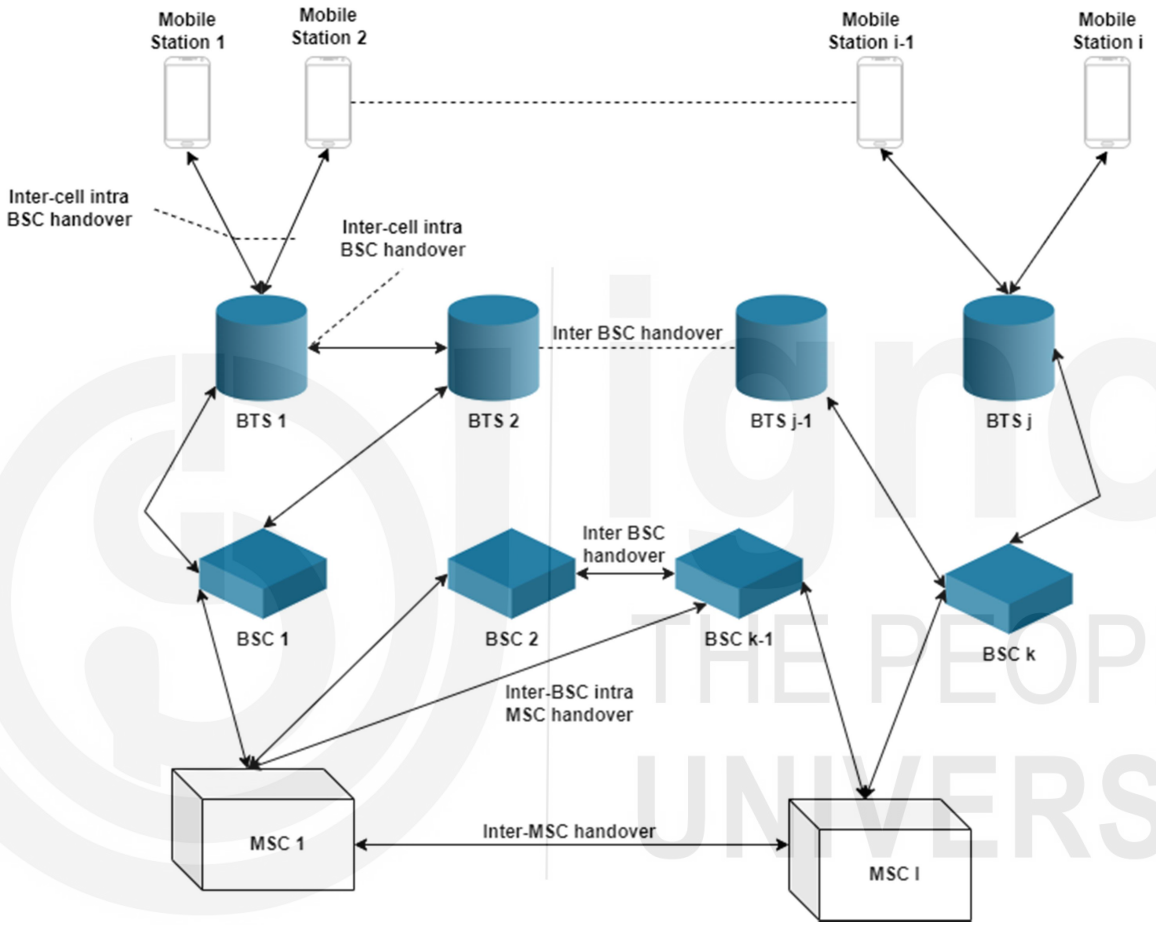


Figure 6

The following are different types of handovers and the handover procedures in a GSM network:

4.5.1 Handover Types

For handoff/handover processes, different cellular systems adhere to different rules. As 3G standards and technology have advanced, many mobile devices can share a single channel and share the same frequency bands with nearby cells. As a result, in addition to the traditional techniques, new handover methods have emerged.

Hard handover and soft handover are the two primary types of handover. The following are discussed here below:

Hard Handover

In order for another base station to take over an existing radio link, the current radio link must be temporarily dropped. This is known as a hard handover. A call's progress is diverted during this form of handover from one base station to another base station as well as from its present transmit-receive frequency pair to another frequency pair. During this time, a call that is in progress cannot exchange voice or data. Call drop or call cut-off refers to this pause in call transmission. The handover only lasts a few milliseconds (at most, 60 ms), and the user rarely notices the interruption.

When the signal strength is weak and the error rate is significant, handover to another cell is necessary. Hard handovers occur in GSM systems.

Soft Handover

There is soft handover in 3G CDMA networks. An MS at the boundary of two neighbouring cells experiences soft handover if there are no call dropouts as a result of the handover in the boundary zone. It provides an MS with smooth connectivity. For a call to be transferred from one cell to another via soft handover, the radio link does not need to be broken. It is possible for a mobile device to connect to many base stations at once.

4.5.2 Handover in GSM

Figure 6, depicts the handover when a mobile station MS switches between cells or when the volume of traffic via a particular stage increases significantly. Here are some examples of these handovers:

Inter-cell Handover

Multiple cells are formed when multiple BTS antennae using SDMA are positioned in various directions. The MS, BTS, and BSC continuously measure the signal intensity at the RRM (Fig. 4.9) sub-layers. The administration of handovers falls under the purview of the RRM. There is handover from one cell to another when the signal weakens for a variety of reasons (such as the MS moving from the cell in which it is currently situated to the boundary region of another cell). This is named as Inter-cell handover.

Inter-MSC Handover

When there is a lot of traffic coming from the cells and BSCs, load balancing also undergoes handover. A cell may transfer a call that is currently in progress to another MSC. The handover is carried out over a wired line due to the fact that the two MSCs are interfaced through PLMN as shown in Figure 7

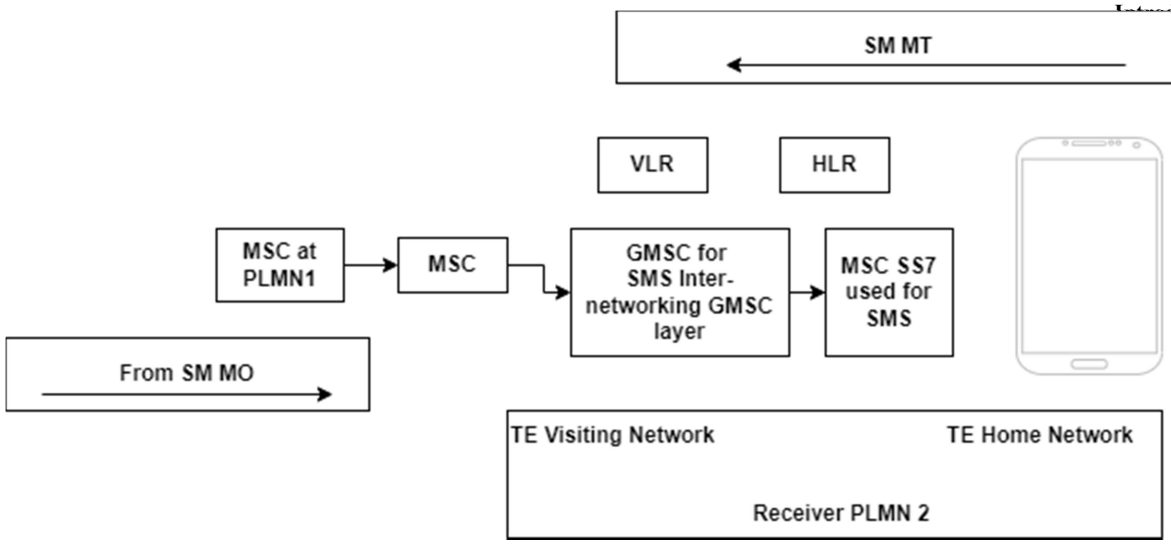


Figure 7

Inter-BSC Handover

When cell and BTS traffic is heavy, handover also occurs for load balancing. An MSC is connected to the BSCs. A BTS in a cell may transfer a call to another BSC linked to the same MSC while the call is still in progress. The handover is conducted over a wired connection because the BSCs connect to the MSC interface using PCM.

Inter-BSC and Inter-MSC Handover

When there is a lot of traffic coming from the BSCs, BTSs, and cells, there is also a handover for load balancing. BTSs link up with a BSC, and BSCs link up with an MSC. A cell may transfer a call that is being handled by a BTS to another BSC that is connected to a separate MSC.

Intra-cell Handover

The signal quality deteriorates because of interference at specific frequencies. In these circumstances, the BSC can transfer the call to a different cell frequency.

Inter-cell and Intra-BSC Handover

The BSC can switch the call to a different BTS channel of the same BSC when an MS moves to a neighbouring cell and experiences poor signal quality. The handover within the BTSs takes place over a wire since each BTS has a different radio channel, but this is because each BTS connects to the interfaced by PCM. Because of this, the BSC chooses a new radio channel (radio carrier frequency).

Inter-Cell and Intra-MSC Handover

The following messages are exchanged during the inter-cell and intra-MSC handover:

- ✓ A signal report is sent by the RRM sub-layer from MS_i to BTS_i and from BTS_i to BSC_i. In the event that a handover is required, BSC_i notifies MSC_i of the need.
- ✓ Another BSC_j receives the handover request from MSC_i and responds by allocating radio resources and transmitting the activated channel to a different BTS_k.
- ✓ BTS_k notifies BSC_j of the channel's acknowledgement, and BSC_j notifies MSC_i of the handover request grant via a message.
- ✓ MSC_i sends a handover command to BSC_i, which then relays it to BTS_i and BTS_i to the RRM layer of MS_i. The RRM instructs the MS radio interface to use a different channel connected to BTS_k.

There is call handover to BTS_k, and voice or data exchange begins there. The MSs in a cell have access through BTSs. In a next-generation network, a WLAN (wireless LAN) can also access BTS. By handing off between BTSes, BSCs, or MSCs as well as the interstitial LANs, the BTSs in new-generation (2.5G) networks enable mobility. This makes sure that the user has continuous (uninterrupted) connectivity.

4.6 SMS

A GSM or any smartphone that connects to a GSM PLMN provides a number of teleservices, including phone, voice data (such as an automated message played on incoming calls), MMS, and SMS to another GSM or PSTN network. These SMS service attributes are as follows:

- Each SMS is limited to 160 characters.
- Synchronous case transmission in GSM

  SMS and voice over GSM data transfers happen simultaneously. An SMS is also transmitted over a GSM channel as synchronous data. There are no in-between acknowledgements, and FEC is used to fix any transmission issues. Signaling System No. 7 (SS7), a worldwide signalling channel that uses data link layer protocols for BSC and MSC in mobile networks, is used by SMS services.

- SMS can also use asynchronous transmission services.

  A service provider is always connected to an SMS sender. The service provider makes use of SS7-based transmission channels like SMS SADCCH. As a result, whether the sender is on a foreign network and the recipient is on any other network, SMS service is constantly offered by the service provider.

- Stateless

  Stateless An SMS has no state. It implies that an SMS is not considered to be related to the prior state by SMS signalling and protocol (SMS).

- Self-configurable

  Self-configurable GSM teleservices, bearer, WAP, or HTTP are all used to transmit SMS messages.

- Through way-to-SMS, a well-known website, an SMS can be delivered over the Internet.
- PLMN's receiver network's independence

  At the recipient, an SMS can be sent on a visiting network without using the MSC for SMS or another PLMN interface.

  - Non-repudiable

    You can always find the mobile origin, HTTP site, or SMS sender. It is also possible to track a hacker website or server that is pretending to be the sender's mobile device.

4.6.1 SMS Architecture

The CM sub-layer actions were displayed in Figure 4. Call establishment, maintenance, and termination are supported by the CM sub-layer protocol. The SMS is likewise managed and supported by the CM sub-layer. SMSs employ SADCCH.

4.6.2 SM MT and SM MO

A service provider of teleservices is used by sender mobile terminal mobile terminal equipment (SM MT) for the SMS service. SM MT connects to PLMN2, which connects to the sender's PLMN1 through PLMN2. SM MO, or sender mobile terminal mobile origin equipment, employs a tele- and SMS service provider. The SM MO connects to PLMN1, which connects to the receiver's PLMN2 in turn.

The interfaces between sender SM MO and PLNMI are shown in **Figure 8.**

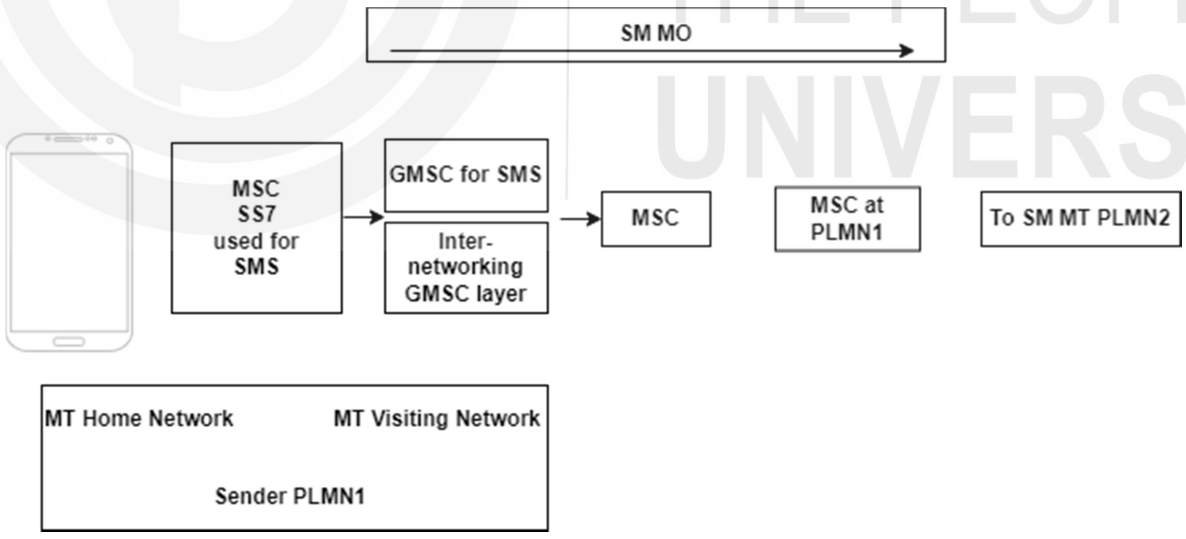


Figure 8

The interfaces for SM MT at the receiver are shown in Figure 7.

4.6.3 SMS as a Carrier of Information

An SMS is a crucial informational tool. A missed phone message or a birthday message are examples of information. There is a 160-character limit for each sender message and any other brief messages (bytes).

Status Enquiries, e-Booking, and e-Ticket Services.

These offerings make use of SMS. A message is sent from the sender's phone. It serves as the input for a computer programme running on the receiver server, such as a train seat reservation status inquiry sent through SMS to a predetermined number. Input data is Message <Name> PNR <PNR number> The status database server at the receiving end responds to a query sent by the status server at the receiving end. In response to the question, the response is sent back to the sender. Other instances include purchasing a movie ticket, ordering a gas cylinder by SMS, or checking the status of a train.

Value-added service

An example of a value-added service (VAS) that a service provider might offer is sending a short message to an email address as part of an SMS or SMS-based poll for a dance competition.

A service provider might offer a VAS, like paying the recipient with funds sent by the sender using a bank's VAS. A bank might provide a VAS for customers who want a chequebook or want to transfer money to another account.

Chat service

A chat service is frequently used for maintenance or as a software installation manual. The customer and the software maintenance engineer communicate over mobile short messages.

Alert service

Mobile users frequently utilize alert services for storm warning, weather, stock market quotes, bank account balance (credit or debit), weekly bank account balance, magazine renewal, and jewellery festival concessions.

4.6.4 SMS Applications

There are numerous uses for SMS. A maximum of 160 bytes are regarded to be the input for an SMS sender message. The input is processed via an API used by mobile computing applications. There are now many different sorts of SMS applications accessible for mobile devices. A list of suggestive applications is shown below:

1. Financial transactions and banking services
2. Book tickets for a flight, a train, or a bus
3. Health care
4. Cab service
5. Requests for maintenance
6. Investigation findings
7. Match alerts for cricket or football

Applications utilize commands for AT attention (AT). AT instructions were first used in the standard Hayes modem. Applications for mobile computing use SMS in text mode or protocol data units (TPDU)

The commands AT+ CMGR (read message) and AT+CMGS are two examples (send message)

4.7 GPRS

Data rates of TCH/13.4, TCH/HS 11.4, TCH/12.8, TCH/F14.4, TCH/F14.4, TCH/F9.6, and TCH/F4.8 are offered by the GSM system. These speeds are suitable for voice data transmission but are insufficient for high-speed data transfer. For a GSM system to be able to offer data services, such as the transfer of large files and Internet access, speed enhancement is necessary.

Different coding and multiplexing techniques are used by new 2G data services like general packet radio service (GPRS) and high-speed circuit-switched data (HSCSD) to give GSM consumers fast transmission speeds.

The following are the three main strategies for increasing transmission data rates:

1. Pooling numerous slots in a network that uses packet switching. An illustration of this kind of speed improvement is GPRS
2. Combining several circuit-switched network slots. Since it combines many time slots for high-speed circuit-switched data transfer, HSCSD, for instance, is an enhancement over GSM.
3. Using additional technology, such as the short-range digital enhanced cordless telecommunications system (DECT).

The next sections provide a detailed explanation of these new 2G data services as well as the methods employed to increase speed.

4.7.1 General Packet Radio Service

A speed-enhanced data transfer service created specifically for GSM systems is called General Packet Radio Service (GPRS). Data packetization and simultaneous transmission of packets over several channels provide faster data delivery. The European Telecommunications Standards Institute(ETSI) is the body that established the GPRS standard .

There are two switching modes: (i) circuit switching, wherein, a connection is first established and then the entire data stream is transmitted through the path that has been established during the connection, and (ii) packet switching, wherein data packets may, at any given time, travel through any number of time slots, channels, paths, or routes depending on the free slots that are available at that time. The receiver then reassembles the packets into the data's original sequence.

For the data transfer and Internet access of mobile stations, GPRS is a packet-oriented service. For packetized transmission from a mobile station, it makes use of the free slots and channels in TDMA mode of a GSM network.

A single mobile station transmits data packets throughout a number of time intervals. Serving GPRS support nodes are deployed by GPRS (SGSNs). An SGSN interacts with other SGSNs and base station controllers (BSCs) in different ways. In addition, GPRS interfaces with SGSN and a packet data network like the Internet using gateway GPRS support nodes (GGSN). As with a GSM system, the BSCs also communicate with the MSCs.

Therefore, it is possible to think of the GSM system as a GPRS system's subsystem. In order to link mobile stations to the Internet and packet data networks at greater data rates and to connect mobile stations for voice data transfer, GPRS uses the GSM physical layer.

Transmission speeds of 22.4 kbps, 14.4 kbps, 11.4 kbps, 9.6 kbps, and 4.8 kbps are permitted over the voice data traffic channel in GSM. According to the likelihood of transmission mistakes, GPRS includes four different encoding techniques that allow transmissions at speeds of 21.4 kbps, 15.8 kbps, 13.4 kbps, and 9.05 kbps, respectively. These are referred to as coding schemes 4, 3, 2, and 1, respectively. Eight TDMA time slots are available.

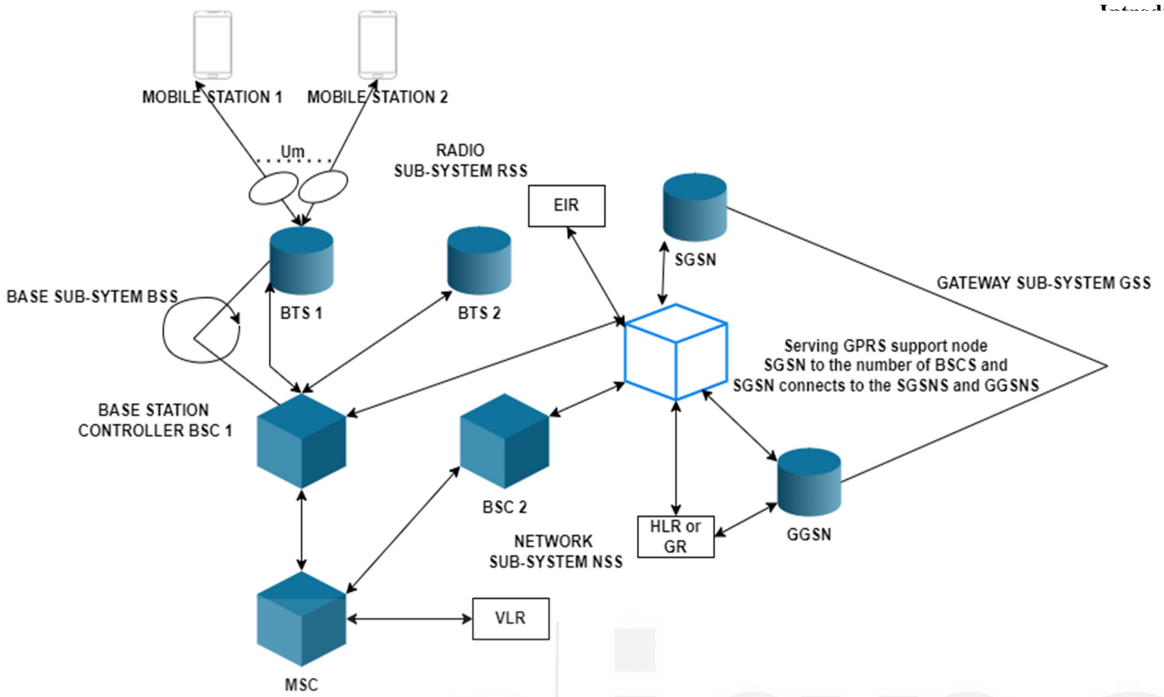
When data from a specific TE (terminal) is transmitted simultaneously in time slots 0, 1, 2, 7, the data rates for coding scheme 4 are 21.4 kbps, 42.8 kbps,..., and 171.2 kbps, and for coding scheme 1, they are 9.05 kbps, 18.2 kbps, and 72.4 kbps.

In a half-duplex transmission, downlink and uplink might occur at different times, every 3.577 ms in GSM. For practical reasons, it's possible that one mobile station won't be able to use all eight of the available slots. In the eight-slot data frame for the GPRS transmission, there may be k time slots for receiving bits and k for transmitting.

The eight slots can only be used up to k times at once (k, k', and k) "each have a value of eight or less. For instance, a class 10 mobile station has the symbols k, k', and k "– 4, 2, and 5 correspondingly.

4.7.2 GPRS System Architecture

The GPRS system architecture is depicted in Figure 9



It displays four subsystems: the network switching subsystem (NSS), the gateway subsystem (GSS), the radio subsystem (RSS), and the base subsystem (BSS). These subsystems each contain a number of BSCs, MSCs, SGSNs, and GGSNs.

These are the architectural components:

- A number of (MSs), (BTSs), and (BSCs), BSC_1, BSC_2,.., BSC_k, make up the RSS.
- Similar to the cypher key saved in the SIM in GSM, an MS with GPRS capability contains a cypher key sequence number (CKSN). Similar to the TMSI in the SIM, it also stores a temporary logical link identification (TLL).
- The serving GPRS support nodes (SGSNs) SGSN-1, SGSN-2,..., SGSN-i and mobile services (MSCs) MSC-2, MSC-j make up the NSS.
- A GPRS context is created by the GPRS system and is stored in both the MS and the SGSN. The context contains details on the status of MS, a data compression flag, cell and channel identities for packet data, and routing area data.
- The SGSN is used to store the equipment data in a GPRS equipment identity register (EIR). EIR supports the subsystems for operation, maintenance, and authentication.
- A number of BSCs at the RSS layer are connected to each SGSN and MSC in the NSS layer. The frame-relay protocol is employed by the SGSNs for this.
- Home location-cum-GPRS registers (HLR/GRs) are m in number, and (VLRs) are in n number. The HLR part of an HLR/GR saves information about mobile stations, while the GPRS register (GR) part stores GPRS data. Like the VLR in GSM, the GR keeps track of the

positions of mobile stations. As in the GSM sub-system, VLRs are connected to MSCs.

- The GSS, which comprises of the SGSNs and GGSNs, offers GPRS connectivity to the Internet and other public data networks (PDNs).
- The MSs — MSi to MSi — connect to the transceivers, BTS_1 to BTS_j — when a mobile station transmits voice data using the GPRS system's GSM sub-system. Assume that (as shown in Figure 6), the q^{th} BSC connects to a number of BTSs and the r^{th} MSC connects to a number of BSCs. In a GPRS system, mobile stations MSi to MSi connect to transceivers, (BTS_1 to BTS_i) to transmit GPRS voice data or data-only packets. The k^{th} SGSN also connects to a number of BSCs. The k^{th} SGSN is linked to a variety of other SGSNs and GGSNs.
- The GGSNs connect to a packet data network, like a TCP/IP network, for instance.

4.8 HIGH SPEED CIRCUIT SWITCHED DATA

A new technology that enables simultaneous usage of numerous time slots is high-speed circuit-switched data (HSCSD). The ETSI has established HSCSD as a 2.5G, GSM Phase 2 standard. Circuit-switched data (CSD), the initial data transmission method used in GSM systems, has been improved. Error correcting codes in the original CSD broadcast consumed a significant portion of the GSM transmission bandwidth. However, depending on the radio link's quality, HSCSD offers a variety of levels of error correction. Because of this, HSCSD data rates can reach 14.4 kbps where CSD could only transmit at 9.6 kbps.

HSCSD is able to utilise numerous time slots concurrently. To transport data at a rapid rate, several GSM traffic channels (TCHs) can join forces. A source TE receives several TDMA slots. Except during call setup, a single user receives the time slots. Therefore, HSCSD is a high-speed vice for transfers of time-sensitive images or videos.

It can offer a maximum transmission rate of up to 57.6kbps using a maximum of four time slots. The air interface user rate (AUR) for simultaneous transmission of four TCH/F 14.4 channels is 57.6 kbps per duplex. HSCSD transmits data with a lower latency than GPRS while transmitting regular voice data traffic. Due to the dedicated circuit-switched communication channels, HSCSD provides a higher quality of service than GPRS. HSCSD, on the other hand, uses less bandwidth than GPRS, which is packet-switched and consequently expensive over wireless networks.

4.9 WLL APPLICATION

The WLL network system is depicted in Figure 10.

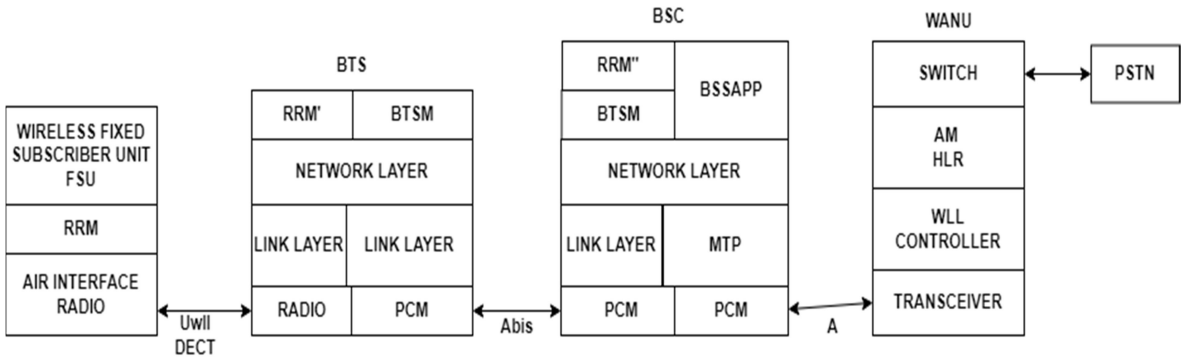


Figure 10

A user is connected to PSTN networks or broadband Internet using radio signals through a wireless local loop (WLL), also known as Fixed Radio Access (FRA) or radio in the loop (RITL). It includes proprietary fixed radio access systems, cordless access systems, and fixed and cellular systems. WLL is implemented using DECT or other technologies, such as CDMA, TDMA GSM, and UMTS 3G, to provide the link between two terminals (PWT or FRT). In addition to being a backup system, WLL aids in the delivery of broadband and telecommunications services in areas without wired or fibre lines.

Exercises

1. Explain the call handover procedure when a mobile station moves.

2. Describe a GPRS system's features, protocols and architecture.

3. Describe when is HSCSD used? How does HSCSD high-speed transmission work? How does data transfer via HSCSD vary from GPRS?

4. Describe the protocols, architecture, and features of the DECT system.

5. What are the different WLL protocols? What types of services does WLL offer?

4.10 SUMMARY

This unit summarizes the following points

- For GSM networks, GPRS is a speed-enhanced data transmission service. Data packetization and simultaneous transmission of packets over various paths to the receiver allow for speed-enhanced data transmission.
- BTS is a transceiver that uses an interface to connect to a BSC at the lower layer and a number of mobile systems at the upper layer.
- A BSC is a controller that interfaces with an MSC via one interface and various BTSS via the A interface.
- MSC is a switching centre that utilises the A interface to link to a number of BSCs, as well as to other MSCs and gateway MSCs (GMSCs). The HLR and VLR are likewise connected to the MSC.

- When a mobile device crosses the border between two cells that are served by two different BTSes, a technique called handover transfers control to the neighboring cell base station.
- SMS is a stateless, non-repudiable short message service with a character limit of 160. Its broadcast is self-configurable, and it is not dependent on the receiver network.
- HSCSD is a novel way to utilise several time slots concurrently. In order to send the data quickly, numerous GSM traffic channels combine, and a source terminal device is given access to a number of TDMA slots.
- WLL is a protocol that uses radio waves to link users to broadband Internet or PSTN networks. It consists of proprietary fixed radio access systems, cordless access systems, and fixed and cellular systems. It uses other technologies, such as DECT, CDMA, TDMA, GSM, UMT 3G, or CDMA, to implement a link between two terminals.

4.11 FURTHER READINGS

1. https://www.spiceworks.com/tech/networking/articles/what-is-gsm/
2. https://www.gartner.com/en/information-technology/glossary/bts-base-transceiver-station
3. https://www.sciencedirect.com/topics/computer-science/home-location-register#:~:text=There%20are%20two%20types%20of,information%20enabling%20charging%20and%20routing.
4. http://teletopix.org/gsm/what-is-hlr-and-vlr-and-its-function-in-gsm/
5. https://www.gsmarena.com/glossary.php3?term=hscsd
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UNIT 5 4G AND 5G NETWORKS

Structure **Page No.**

5.0 INTRODUCTION

The mobile technologies such as MIMO, 4G, 5G have revolutionized the human experience. These mobile technologies have re-defined the way we communicate, collaborate and do business.

The advanced mobile technologies provide fast data access, low latency data transfer, high availability, better coverage and many other benefits. Starting with mobile radios we have come a far way wherein we now have a super-computer capability in our palms.

Modern mobile phones enable us to watch high definition live broadcast, multi-player games, video calling and many other applications.

In this chapter we discuss the technologies behind the 4G and 5G technologies along with its features, use cases and other examples.

5.1 OBJECTIVES

After going through this unit, you should be able to

- understand key concepts of High speed packet access,
- understand the usage of MIMO in High speed packet access,
- understand the key features of LTE and WiMAX 16E
- understand the key features of OFDM and LTE advanced,
- Understand the main features of 5G.

5.2 HIGH SPEED PACKET ACCESS

The high-speed packet access (HSPA) is the wireless technology to enhance the increase the upload and download speeds for 3G networks, UMTS and WCDMA networks. HSPA includes refers to High-Speed Downlink Packet Access (HSDPA) and High-Speed Uplink Packet Access (HSUPA). HSPA needs 3G network.

Modern application such as video streaming, live broadcast, real-time gaming application use HSPA.

Table 1 the key features of HSPA –

Table 1 HSPA Features

HSPA Feature	Brief Details
Peak Upload Speed	5.76MBPS
Peak Download Speed	14.4MBPS for 3G UMTS
Average Upload Speed	1-2 MBPS
Average Download Speed	3-5 MBPS
Round trip time	< 100ms

5.2.1 Working of HSPA

We have explained the working of HSPA below –

- The HSDPA and HSUPA provide low latency and high bit rates. Over 3G, the HSDPA creates a high-speed download channel among users.
- HSDPA uses 10ms transmission duration to enable quicker switching and accommodating the network changes. Faster data traffic scheduling is used to accelerate the data transfer for a single user.
- To efficiently use the network resources HSDPA uses QPSK/16 QAM modulation schemes are used. HSPDA uses various methods such as Short transmission time interval (TTI), Higher order modulation, Fast scheduling and user diversity and Fast link adaptation.
- HSDPA uses efficient retransmission of the missed data packets.
- HSUPA enhances the upload uses a dedicated channel between mobile phone and the station for the data upload.
- HSUPA also quickly retransmits the missed data packets.

The key features of HSDPA are Adaptive modulation and coding (AMC), Multi-code operation, Hybrid automatic repeat request, Higher order modulation, Short transmission time interval, Fast link adaptation and Fast scheduling.

5.2.2 High Speed Packet Access+

HSPA+ uses higher order modulation scheme (64-QAM for downlink and 16-QAM for uplink) and uses Multiple Input Multiple Output antenna technology and other enhancements.

Given below are the main features of HSPA+

HSPA Feature	Brief Details
Peak Download Data transfer	21MBPS with 64-QAM
Peak Download data rate	HSPA R9 downlink 126MBPS

Peak Upload data rate	HSPA R9 downlink 23MBPS
Modulation	64-QAM for downlink and 16-QAM for uplink

☞ **Check Your Progress 1**

1. The peak upload speed of HSPA is _____
2. The Average Download Speed of HSPA is ____
3. HSDPA uses ___ for efficient use of network resources.
4. The Peak Download Data transfer in HSPA+ is ____ with 64-QAM
5. The Modulation used by HSPA+ is _____

5.3 MIMO IN HSPA

Multi Input Multi Output (MIMO) uses multiple antennas for transmitting and receiving to improve the data transfer rates.

The detailed working of MIMO in HSPA is given below –

- MIMO uses antennas and "processing" at both transmitter and receiver end to create multiple, uncorrelated radio streams between the transmitter and receiver.
- The radio streams use same frequency and time that multiplies the capacity in the same spectrum.
- As the antennas increase, the data transfer rates increase using the same amount of power and the spectrum.
- Each increase in the order of MIMO, we can double the data peak rate. For instance a 2x2 MIMO doubles the peak data rate over 1x1 MIMO.

We have depicted a 2x2 MIMO in Figure 1

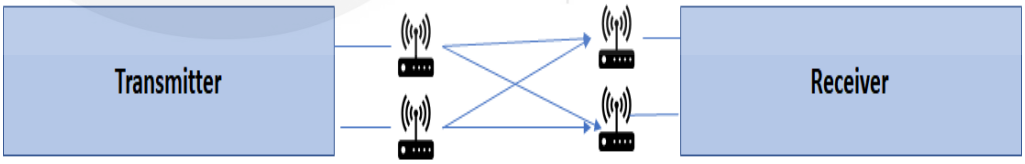


Figure 1 2x2 MIMO

As we have 2 antennas at transmitter and at the receiver end, the data transfer rate is doubled as compared to a 1x1 MIMO.

5.4 LTE AND WIMAX16E

LTE is the successor of UMTS and CMDA and provided 50 times better performance than existing cellular networks.

Long term evolution (LTE) was evolved as the mobile gaming, mobile video gained popularity. LTE provides high data rate, flexible bandwidth, packet optimizations and low latency. LTE also provides great quality of service. LTE uses both frequency

division duplex (FDD) and Time division duplex (TDD). FDD data uplink and data downlink uses different frequency and in TDD data uplink and data downlink are separated in time.

LTE also supports MIMO through which the base station transmits multiple data streams simultaneously.

Table 2 provides the key features of LTE

Table 2 LTE Features

Feature	**Brief details**
Peak Download Link	300MBPS
Peak Upload Link	75 MBPS
Frequency	1.4MHZ to 20 MHZ
Compatibility	GSM/EDGE/UMTS on 2G/3G spectrum.
Use cases	VoIP, live streaming, multimedia delivery, broadband internet

The architecture of LTE is depicted in Figure 2

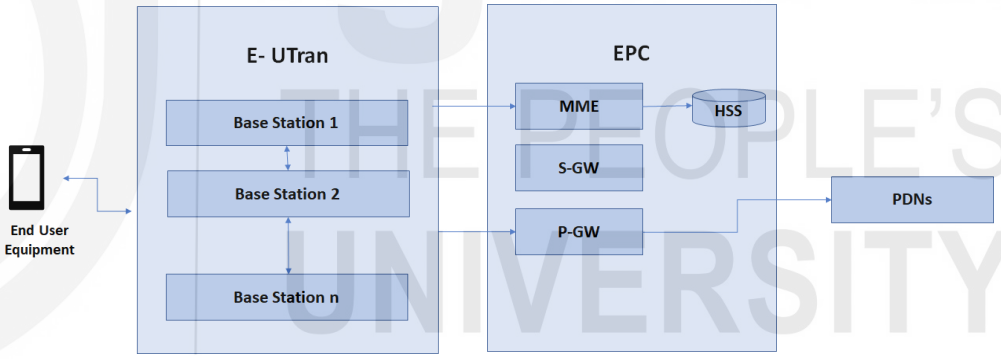


Figure 2 LTE Architecture

The end user equipment is a mobile device that handles the communication and data streams. The Universal Integrated Circuit Card (UICC) run Universal Subscriber Identity Module (USIM) application for managing the data such as phone number, security keys and others.

The E-UTRAN manages the communication between the mobile device and the EPC through base stations. Each base station provides the network for the mobile phone through one or more cells. The base station sends and receives the radio signals. The base station also sends the handover command for the mobile phones.

The evolved packet core network (EPC) manages the core functions and message routing. Given below are the key components in EPC –

- The mobility management entity (MME) manages the high level mobile operation by sending messages to Home Subscriber Server (HSS).
- The HSS database has the subscriber information.

- Packet Data Network (PDN) Gateway (P-GW) communicates with the packet data network (PDN).

- The serving gateway (S-GW) is the proxy for data transmission from the base station and P-GW.

5.4.1 WIMAX 16E

WIMAX is the broadband internet that supports various frequency bands. WIMAX uses sub-channels wherein the transmit channels are segregated into multiple parallel sub-channels that are assigned to the users. When the proximity of the user to the tower is high, the sub channels will be more.

The main features of WIMAX is given in table 3 -

Table 3 WIMAX Features

Feature	**Description**
Frequency band	Various frequency bands up to 11 GHZ
MIMO	2x2 MIMO
Modulation	QPSK for longer range modulation and 64 QAM for shorter range modulation
Security	AES based authentication
TDD	For uplink and downlink

Figure 3 WIMAX Features

5.4.2 Ultra-Wide Band

Ultra-wide band transmits the data with more than 500MHZ bandwidth spectrum. Ultra-wide band uses low energy for both high bandwidth and short-range communication.

Ultra-wide band uses short pulses to achieve greater location accuracy. An ultra-wide band can determine the location and distance between two ultra-wide band enabled devices with high degree of accuracy. For example, we can use Ultra-wide band for automatically opening the gate when the car approaches it. Another use case for ultra-wide band is that a smart phone can use short pulses to unlock the car door.

The main applications for ultra-wide band are mobile telephony, radar technology, wireless data transfer, real time location management, mobile TV, high speed Internet, video calls and digital security keys.

Table 4 provides the key features of Ultra-wide band

Table 4 Ultra-wide band features

Features	**Description**
Average data transfer rate	Downlink 5.9 MBPS
Peak Data downlink	326 MBPS for LTE 4 x 48
Peak Data uplink	88 MBPS for LTE 4 x 48
Bandwidth	500 MHZ
Latency	50 ms

5.4.3 Broadband Wireless Access

Broadband wireless provides a high speed internet access over a larger area. Wireless broadband uses radio waves to connect to the Internet backbone to provide high speed Internet access. Wireless broadband provides asymmetrical downlink and uplink data transfer rates.

Table 5 provides the main features of broadband wireless –

Table 5 Broadband wireless features

Features	Description
Average data transfer rate	~1.5MBPS
Data downlink	100 MBPS
Data uplink	50 MBPS
Bandwidth	More than 1 MHZ
Range	About 50KM

5.5 4G NETWORKS: HS-OFDM, LTE ADVANCED

4G networks support data transfer rate of more than 100MBPS. Due to this high data transfer rate, 4G is used for high definition video streaming, mobile gaming and such applications.

4G requires at least 40MHZ bandwidth for supporting the high data transfer rate. 4G also supports high mobility and roaming across various networks. The 4G system design requires LTE Advanced or WiMAX 402.16m

5.5.1 OFDM

Orthogonal Frequency Division Multiplex (OFDM) is a 4G signal format that provides multiple access schemes. OFDM uses multiple close spaced carriers each with low rate data stream. The transmitted data is shared across all carriers to provide high fault tolerance. In the multi-carrier scenario, OFDM uses code multiplexing and each of the carriers use mutually exclusive orthogonal codes.

For downlink it provides orthogonal frequency division multiple access (OFDMA) and for uplink it provides single channel orthogonal frequency division multiple access (SC-FDMA).

The usage of multiple carriers each with low data rate makes the OFDM resilient by shielding against narrow band fading.

Frequency Domain Equalization

By using appropriate frequency domain equalization at the receiver end, the direct sequence CDMA (DS-CDMA) provides high performance. Single carrier FDMA (SC-FDMA) technique uses frequency-division multiple access FDMA. The SC-FDMA encodes the sub-carriers.

MIMO

4G uses advanced multi-user MIMO in which multiple MIMO transceivers pre-code using signal processing algorithms.

5.5.2 LTE Advanced

LTE Advanced (LTE-A) is an enhancement over the LTE that provide higher data transfer rates, better performance mainly at the cell edges.

Table 6 provides the key features of LTE Advanced –

Table 6 LTE Advanced Features

Feature	Description
Peak data uplink	500MBPS
Peak data downlink	1 GBPS
Latency	< 5ms for one way packet transmission
User throughput	3x LTE
Use cases	Streaming media, High Definition Video streaming, Live TV

5.5.3 WIMAX 16M

WIMAX is the commercial name for Worldwide Interoperability for Microwave Access. WiMAX is a connection-oriented technology. The physical layer (PHY) and the media access control (MAC) layer are standardized by the WifiMax technology.

The physical layer operates in the bandwidth between 1.25MHZ and 20 MHZ and uses OFDMA for data transfer. The physical layer also supports MIMO antennas for high performance.

The MAC describes the technologies such as Internet protocol (IP), ethernet, asynchronous transfer mode (ATM) along with methods for data security, data transfer, data classification, secure communication, encryption methods (such as AES, DES encryption standards).

Table 7 provides the main features of WiFiMax –

Table 7 WiFIMax features

Feature	Description
Bandwidth	1GBPS
MIMO	Single user MIMO and multi-user MIMO
Multiplexing	TDD and FDD
Frequency	450-470 MHZ to 3.600 GHZ
Use cases	Broadband internet, High Definition Video streaming, Mobile Internet, Multimedia streaming.

Check Your Progress 2

1. The Increase in the order of MIMO, _____ the data peak rate.
2. The peak download link of LTE is ___
3. The frequency of LTE is _____.
4. _____ in LTE manages the core functions and message routing.
5. The Data downlink of broadband wireless is _____
6. The Frequency of WiFiMax is _____

5.6 FEATURES OF 5G NETWORKS

5G is the next generation of wireless technology that aims to provide high data transfer rate. 5G leverages many technologies such as MIMO, Software defined network, Internet of Things (IoT), thousands of simultaneous hyperlink connections, cloud computing and others. 5G enables enterprises to securely share the data and services among its employees and customers.

5G uses shorter millimeter waves between 30GHz and 300GHz enabling faster data transfer rates and provides ultra-low latency, high reliability, increase network capacity and rich user experiences. 5G delivers 1000 times more capacity than 4G.

5G also supports many use cases such as real time video streaming, big data processing, digital media services, connected vehicles, autonomous driving, virtual reality, telesurgery, multi-player gaming, immersive shopping, faster cloud access and others.

Table provides the key 5G features –

Feature	Description
Latency	1 ms
Data transfer rate	10 GBPS
Availability	99.999%
Network energy consumption	90% reduction in network energy consumption

5.7 SUMMARY

The high-speed packet access (HSPA) is the wireless technology to enhance the increase the upload and download speeds for 3G networks, UMTS and WCDMA networks. The HSDPA and HSUPA provide low latency and high bit rates. Over 3G, the HSDPA creates a high-speed download channel among users. The key features of HSDPA are Adaptive modulation and coding (AMC), Multi-code operation, Hybrid automatic repeat request, Higher order modulation, Short transmission time interval, Fast link adaptation and Fast scheduling. Multi Input Multi Output (MIMO) uses multiple antennas for transmitting and receiving to improve the data transfer rates. LTE is the successor of UMTS and CMDA and provided 50 times better performance than existing cellular networks. WIMAX is the broadband internet that supports various frequency bands. Ultra-wide band transmits the data with more than 500MHZ bandwidth spectrum. Ultra-wide band uses low energy for both high bandwidth and short-range communication. 4G networks support data transfer rate of more than 100MBPS. Orthogonal Frequency Division Multiplex (OFDM) is a 4G signal format that provides multiple access schemes. WiMAX is a connection-oriented technology with the physical layer (PHY) and the media access control (MAC) layer are standardized by the WifiMax technology. 5G uses shorter millimeter waves between 30GHz and 300GHz enabling faster data transfer rates and provides ultra-low latency.

5.8 SOLUTIONS/ANSWERS

Check Your Progress 1

1. 5.76MBPS
2. 3-5 MBPS

3. QPSK/16 QAM modulation schemes
4. 21MBPS
5. 64-QAM for downlink and 16-QAM for uplink

Check Your Progress 2

1. doubles
2. 300 MBPS
3. 1.4MHZ to 20 MHZ
4. evolved packet core network (EPC)
5. 450-470 MHZ to 3.600 GHZ

5.9 FURTHER READINGS

References

Mobile Computing 3rd Edition by Raj Kamal - https://www.amazon.in/Mobile-Computing-Raj-Kamal/dp/0199455414

UNIT 6 MOBILE IP NETWORK LAYER

6.0 INTRODUCTION

One of the main reference model for the data transmission is called open system interconnection (OSI) that defines seven layers. TCP/IP is another model that defines five layers.

We shall look at then layers for both OSI and TCP/IP model in table 1 and table 2 respectively.

Table 1 OSI Layer and Key features

OSI Layer	Key Features
Layer 1 Physical Layer	The layer establishes the physical connection between the devices and sends and receives the data over the wire.
Layer 2 Data Link layer	The layer links the devices
Layer 3 Network Layer	The layer is responsible for transmission of data from one device to another.
Layer 4 Transport layer	The layer is responsible for resequencing of data and retransmission if required.
Layer 5 Session Layer	The layer is responsible for establishing connection and authentication
Layer 6 Presentation layer	The layer is responsible for data formatting and encryption
Layer 7 Application Layer	The layer is responsible for running the application

TCP/IP model defines five layers as given in table 2.

TCP/IP Layer	Key Features
Layer 1 Physical Layer	The layer is responsible for physical connection
Layer 2 Data link layer	The layer is responsible to move the data frames
Layer 3 Network Layer	The layer is responsible for managing the packets that move across the network
Layer 4 Transport layer	The layer is responsible for establishing connection across application through various ports.
Layer 5 Application layer	The layer manages the applications that require network access

The TCP IP model information is communicated through packets. Each packet contains details such as their destination address and headers. TCP IP model each of the layers at the sender end add encoding and at the receiver and each of the layers decode the data.

Currently IPv4 is a popular standard protocol for the internet. The latest internet protocol version is IPv6 that uses 128 bit address. UDP (User Datagram Protocol) and ICMP (Internet Control Message Protocol) or other protocols used for data transmission. Udp is a stateless protocol where in the datagram does not precedes the previous one nor succeeds the next one. Udp is a popular protocol for streaming videos and gaming use cases. Icmp is a connectionless protocol mainly used for caring messages reporting errors.

In this unit we shall examine the core concepts of mobile IP networking.

6.1 OBJECTIVES

After going through this unit, you should be able to

- understand key concepts of mobile IP,
- understand various encapsulation and route optimization in IP Header,
- understand the concepts of mobility binding,
- understand the concepts of cellular IP,
- understand the mobile IP with IPV6,
- understand various concepts of IP Secuirty.

6.2 MOBILE IP

The mobile IP allows users to communicate without using same IP address. The mobile IP also ensures that the user sessions or managed appropriately.

The main objective of the mobile IP Is to ensure that mobile user's network connectivity is maintained when the mobile user changes location. Let us look at the common terminologies used in the mobile IP:

- Mobile Node (MN) is the mobile device such as smart phone that user has.
- Home Network defines the network which has the original assigned IP of the mobile node.

- Home Agent (HA) is the router of the home network to which the mobile node was originally connected to.
- Home Address indicates the permanent IP of the mobile node.
- Foreign Network defines the current network of the mobile node when the mobile user is on the move.
- Foreign Agent (FA) is the router in the foreign network to which the mobile node is currently connected to.
- Correspondent Node (CN) is the internet device that is connected to the mobile node
- Care-of Address (COA) represents the mobile node's temporary address when it is on the move.
- Foreign agent COA is the COA of the foreign agent.
- Co-located COA, the COA is co-located if the MN temporarily acquired an additional IP address which acts as COA. This address is now topologically correct, and the tunnel endpoint is at the MN. Co-located addresses can be acquired using services such as DHCP.

6.2.1 Need for Mobile IP

When a computer is shifted locations, the IP of the computer that is connected using TCP/IP protocol changes. The IP change is due to various factors such as change in the network, change of the ISP service provider, change of the network route tables, change in the network security and others.

Normally a mobile device is always on the move. If the IP of the mobile device changes, it impacts the connectivity and any ongoing communication. Hence mobile IP is required to ensure that the IP of the mobile device does not change.

6.2.2 Working of Mobile IP

Figure 1 depicts various components and the working of mobile IP

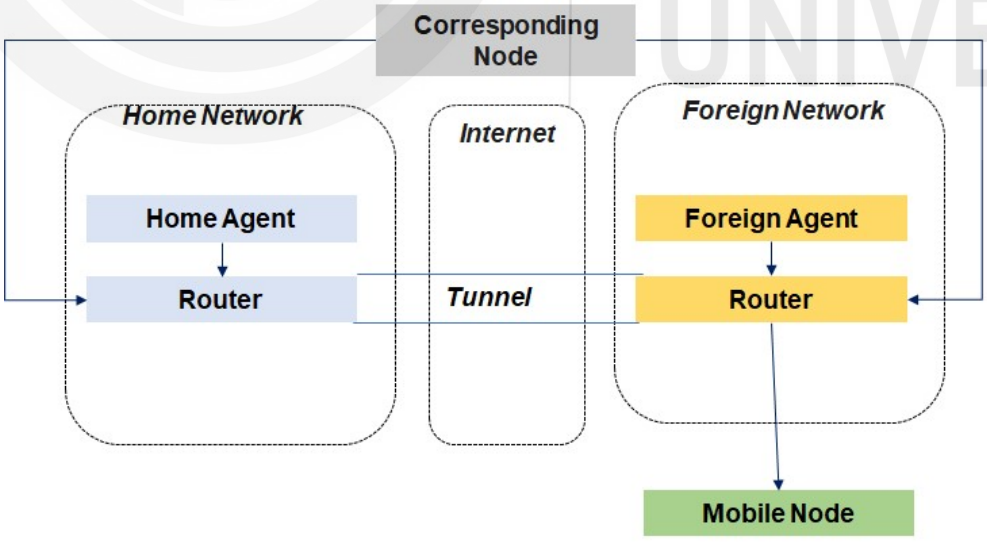


Figure 1: Working of Mobile IP

For the working of mobile IP, given below mechanisms are required:

- Agent advertising – The agents advertise their details on regular basis. The mobile node receives the details and identifies if it is a home network or a foreign network.
- Agent registration – The mobile node initiates the agent registration. If it is foreign agent, it sends a care of address to the home network after which the home agent replies to the foreign agent. The mobile node completes the agent registration.

Given below is the sequence of events for mobile IP:

1. The corresponding node sends the data packet to the home agent.
2. As the mobile node is not in the home network, the foreign network is used.
3. The foreign network sends the care-of-address of the mobile node.
4. A virtual pipe called tunnel is established over the internet between home agent and the foreign agent.
5. The home agent adds the care of address for the data packet and sends it to the foreign agent.
6. The foreign agent decapsulates the data packet and sends it to the mobile node.
7. The foreign agent sends the response from the mobile node to the corresponding node.

☞ Check Your Progress – 1

1. _____ allows users to communicate without using same IP address.
2. _____ is the router of the home network to which the mobile node was originally connected to.
3. _____ is the internet device that is connected to the mobile node
4. _____defines the network which has the original assigned IP of the mobile node.
5. _____ represents the mobile node's temporary address when it is on the move.
6. ____ is used over the internet for communication between home agent and the foreign agent.

6.3 IP HEADER: ENCAPSULATION AND ROUTES OPTIMIZATION

Let us look at the registration flow in greater details as depicted in Figure 2

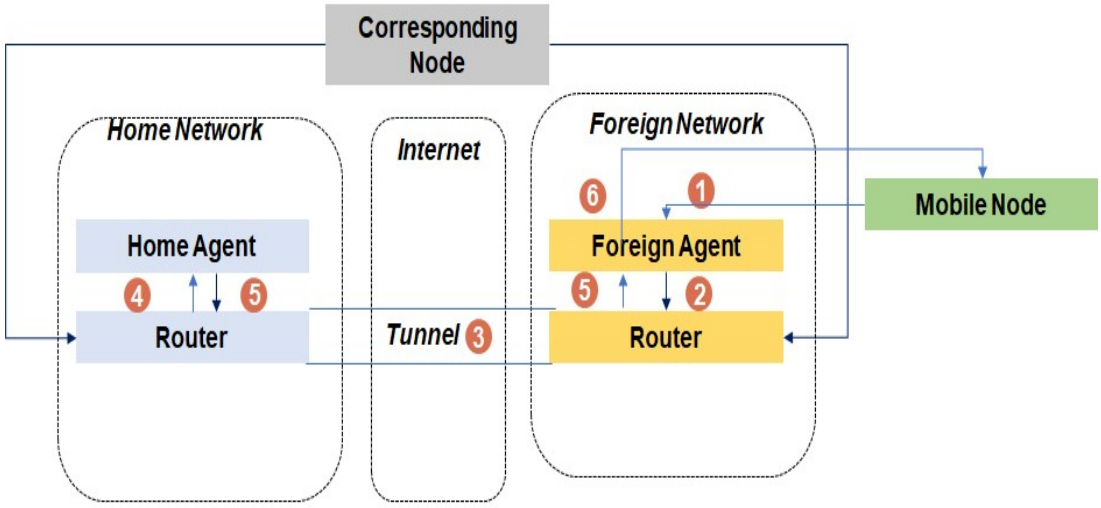


Figure 2: Agent registration Flow

Given below are the detailed steps involved in the agent registration:

1. The mobile node identifies the current network as a foreign network. The mobile node sends a registration request.
2. The foreign agent routes the request to the router
3. The router sends the care of address along with registration request through the tunnel. A tunnel is a virtual pipe that sends the data stream across two connected ends.
4. The router on the home network receives the request
5. The home agent sends the registration response.
6. The mobile node is registered and all the responses from the mobile node are sent to the home network.

6.3.1 Encapsulation of Additional IP Header

We have depicted the encapsulation of additional IP header in Figure 4.

Version	IHL	Service Type	Total Length	
Identification			Flags	Fragment offset
Time to live	Protocol		Header Checksum	
Source Address (Home Agent)				
Destination Address (Care of Agent)				

Figure 3: Additional IP Header encapsulation

The regular packet information mainly consist of Source and destination address and the IP header details. During the registration, the new encapsulated IP headers have below given details as shown in Figure 3:

- IP Version that depicts IPV4 along with header length and the total packet length.
- The flags and fragment offset details of the packet
- Time to live details that define the hops before the packet expiry, protocol and the header checksum
- The IP address of the source home agent.
- The IP address of the destination care of agent.

6.3.2 Minimum encapsulation by IP packet

The minimum encapsulation (ME) combines the data from the original packet as depicted in Figure 4.

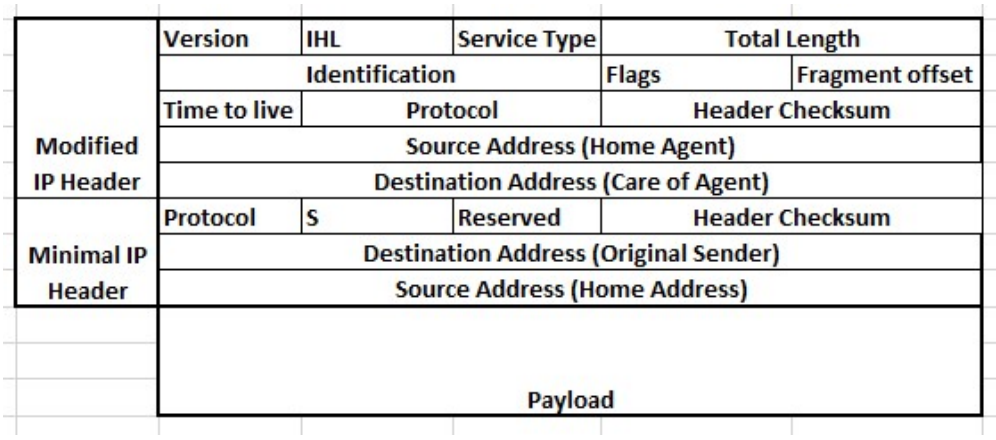


Figure 4: Minimum Encapsulation

Given below are the changes in the Minimum encapsulation:

- The protocol type is specified
- Mobile Node IP address and corresponding node IP address is specified.

6.3.3 Generic Routing encapsulation by IP header

The existing IP headers described below does not provide the tunnel routing information, support recursive encapsulation and the authentication related key. Generic Routing Encapsulation (GRE) headers are added to address the above. The main elements of the GRE encapsulation are given below:

- The time to live flag is set to 1 that results in single forwarding.
- The GRE header is used for recursive encapsulation. The header consists of details such as recursion number, checskum, sequence number, routing information.

6.4 MOBILITY BINDING

We shall discuss the triangular route problem to understand the advantage of mobility binding.

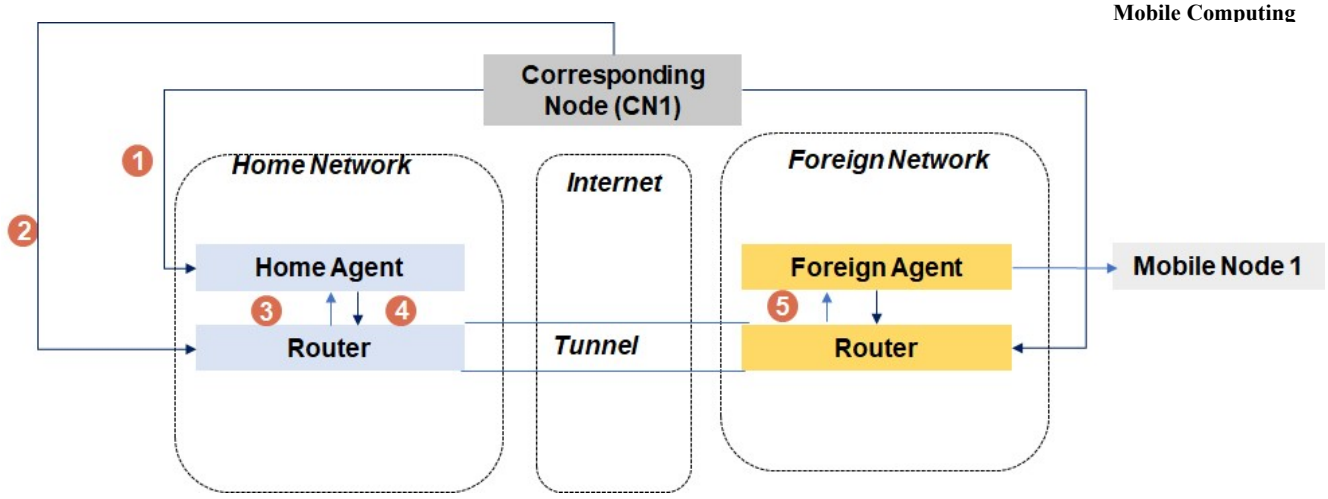


Figure 5: Triangular Routing

When the mobile node (MN1) visits a foreign network that is the home network of corresponding network CN2. Lets consider that CN2 is very close to the corresponding network CN1. For the CN1 to reach the MN1, it has to make a triangular trip visiting the home agent 1 and then reaching the COA at foreign agent as depicted in Figure 5.

The mobile binding optimizes this triangular routing by binding the CN1 directly to the COA of the MN1. This can be achieved using the mobility binding cache which caches the current COA of the Mobile node. The optimization achieved through Mobile binding is depicted in figure 6.

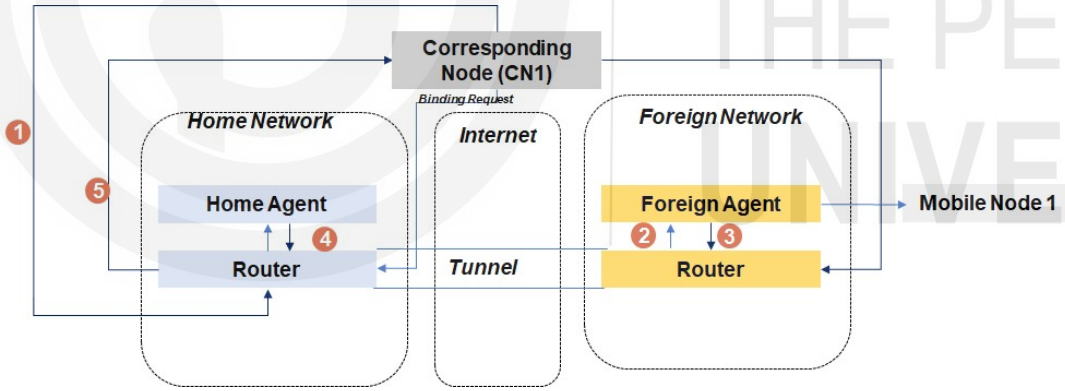


Figure 6: Route optimization through mobility binding

In figure 6 the CN1 directly sends the request to COA of the MN1 achieved through the mobility binding. Given below are the sequence of steps for mobility binding:

- The CN1 and MN1 request the HA1 for binding
- HA1 verifies the blocked status of MN1 and then sends the mobility binding message (consisting of MN1 IP and the current COA of MN1) for the CN1
- CN1 acknowledges the binding message to HA1.
- The binding is established MN1 and CN1.

6.5 CELLULAR IP

Mobile IP faces challenges such as handover duration, registration scalability. The cellular IP addresses these problems by complimenting the mobile IP by providing fast and consistent handover control. Cellular IP facilitates connection across fast moving mobile objects within a cell.

Cellular IP provides following features:

- Cellular IP reuses existing packet formats, encapsulations
- Cellular IP is self-configuring
- Cellular IP provides fast handover within the cell and out of the cell.
- The cellular gateway connects to Internet through mobile IP

The high level architecture of cellular IP is depicted in Figure 7.

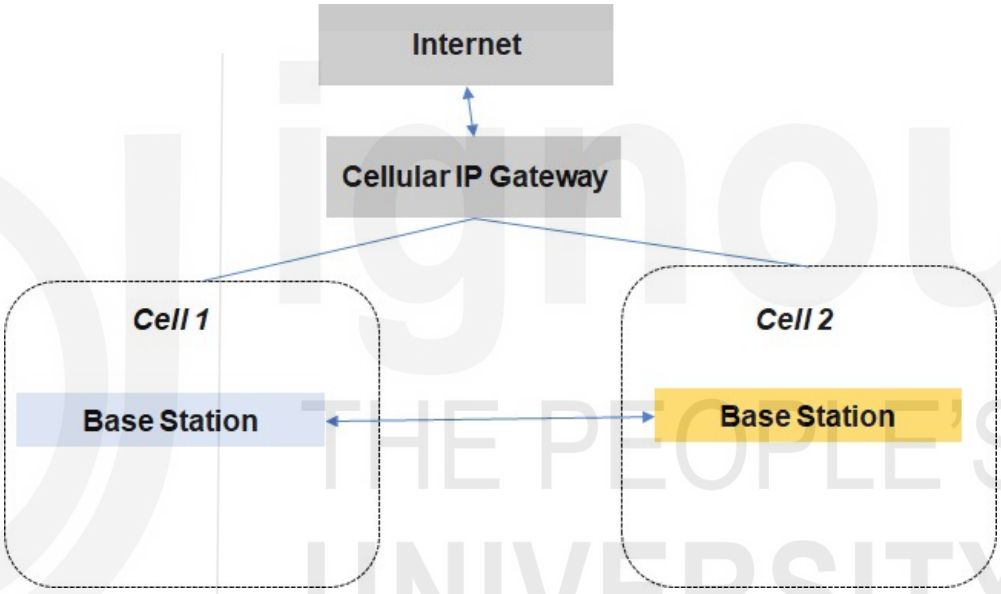


Figure 7: Cellular IP architecture

The cellular IP gateway filters the packets and the packets are routed to the corresponding home agent.

6.6 MOBILE IP WITH IPV6

IPV6 is the latest Internet protocol with 128-bit address. The IPV6 protocol specifies authentication header, routing, extension headers and others. Mobile IPV6 provides the mobility support for IPV6 providing a static IP address even when the mobile device changes location. Mobile IPV6 maintains connection across subnet changes.

Given below are the key features of mobile Ipv6:

- In Mobile IPV6, each mobile node has a static home address IP and the care-of-address IP.
- The home address IP is static and does not change when the location changes. The care-of-address IP switches to new network when the location is changed.
- The mobile node knows the IP of the home agent that makes the binding between home address and the received care of address.

- The home agent maintains a cache that stores the binding details of the home address and the care of address.
- The home agent forwards the data packet to the mobile nodes.
- The mobile node announces the care of address to the home agent.
- Mobile host binding happens through dynamic learning of mobile host binding
- The information packets are all authenticated.

6.7 VOICE OVER IP

Voice over IP (VoIP) facilitates the transfer of voice and multimedia over the Internet Protocol through Internet. VoIP facilitates local as well as long-distance calls. The VoIP enabled devices can send the audio voice, video call, fax and SMS over Internet. VoIP provides high reliability and smoother connection than the analog signals.

Figure 8 depicts a typical VoIP system. On the sender system, the voice and analog data is digitized and encoded at various layers.

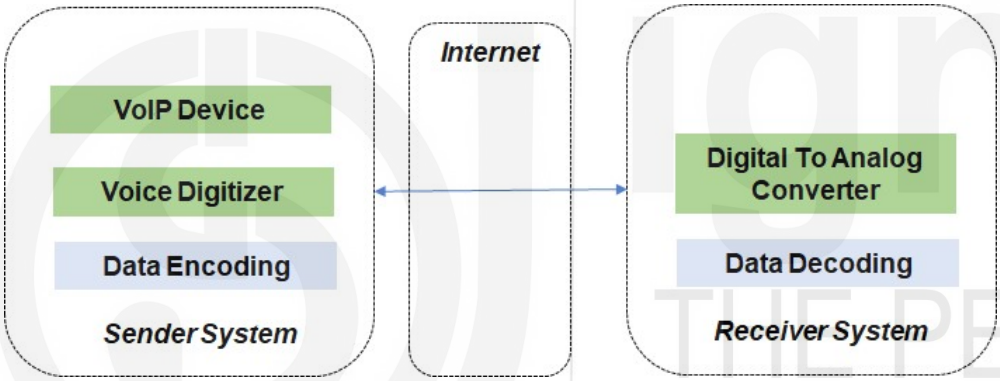


Figure 8: VoIP System

The data is then transmitted over the Internet (broadband, 4G networks and others) to the receiver system. On the receiver system, the data is decoded and digital to analog conversion is done to get the original voice signal.

There are various VoIP protocols such as session initiation protocol (SIP), mobile VoIP (mVoIP). SIP applications can be installed on mobile devices as they support multiple CODECs. mVoIP requires broadband or Wi-Fi networks.

Various modern applications such as Skype, MS Teams, Amazon Chime use the VoIP for audio and video conferencing.

6.8 IP SECURITY

IP security defines the set of protocols to secure the communication between two end points. IP security provides protocols for enforcing authentication, data confidentiality and data integrity. IP Security also defines the protocols for data encryption and data decryption and the associated secure key exchange.

IP Security is used for below given purposes:

- Encrypt the transmitted data.
- Establish the secure IPSec tunnels over the VPN.
- Provide the authentication for the transmitted data.
- Provide router security.

Let us now look at some of the key components of the IP security.

6.8.1 Key Components of IP Security

Encapsulating Security Payload (ESP)

The ESP provides various features such as encryption, data integrity validation and authentication payload. ESP also encrypts the payload data. The key ESP fields are header, encrypted data and integrity check value (ICV) that represents the ESP authentication data. ESP uses SH1 or MD5 for creating the ICV.

Authentication Header

We have depicted the main elements of authentication header in Figure 9. The authentication header provides the key features such as anti replay (prevents unauthorized packet transmission), data integrity and authentication. Algorithms such as SH1, MD5 are used for authentication.

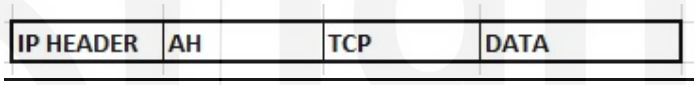


Figure 9: Authentication Header

Security Association (SA)

The security association defines the shared security attributes and ensures the secure communication between two network entities. The SA also stores the packet encapsulation information including the keys, encryption algorithm, sequence number and others.

The security association uses security policy for packet filtering.

Internet Key Exchange (IKE)

IKE defines a secure protocol to dynamically exchange the encryption keys across two devices. IKE finds a security association between the two devices.

We can implement the message content protection by using a unique identifier for each of the packets. The identifier is used to determine the validity of the packet.

IPSec data encapsulation Modes

Transport mode and tunnel mode are the two data encapsulation modes of IPSec data. The transport mode consists of IP header, IPSec header and payload in layer 3. The IPSec tunnel mode provides IPSec header, new IP header over IP header and payload.

6.8.2 Working of IP Security

Given below are the detailed steps of IP Security:

1. Once the host decides the need for IPSecurity, the security policies are applied to the packets.
2. IKE Phase 1 kicks off wherein the communicating hosts authenticate themselves.
3. The security negotiation happens over the secure channel created in step 2.

4. IKE Phase 2 kicks off where the communicating hosts decide the cryptographic algorithms and secret key material used for the algorithms.
5. Exchange of data happens over the secure IPSec tunnel. The encryption and decryption happens through the IPSec SAs.
6. The tunnel is terminated after the completion of the communication or after timeout and the keys are discarded.

☞ **Check Your Progress – 2**

1. In single tier architecture, mobile app interacts with the embedded database ____
2. _____ define the hops before the packet expiry, protocol and the header checksum in the IP Header
3. _____is used for recursive encapsulation.
4. _____optimizes this triangular routing by binding the CN1 directly to the COA of the MN1.
5. ___ compliments the mobile IP by providing fast and consistent handover control
6. _____facilitates the transfer of voice and multimedia over the Internet Protocol through Internet
7. _____ defines the set of protocols to secure the communication between two end points

6.9 SUMMARY

OSI consists of 7 layers including Layer 1 Physical Layer, Layer 2 Data Link layer, Layer 3 Network Layer, Layer 4 Transport layer, Layer 5 Session Layer, Layer 6 Presentation layer and Layer 7 Application Layer. TCP/IP consists of 5 layers Layer 1 Physical Layer, Layer 2 Data link layer, Layer 3 Network Layer , Layer 4 Transport layer and Layer 5 Application layer. The mobile IP allows users to communicate without using same IP address. Mobile IP needs agent advertizing and agent registration. The tunnel between the Foreign agent and the home agent if the mobile device is in foreign network. The regular packet information mainly consist of Source and destination address and the IP header details. The minimum encapsulation (ME) combines the data from the original packet. Mobile binding can be used to optimize the triangular routing. The cellular ip complimenting the mobile IP by providing fast and consistent handover control. Voice over IP (VoIP) facilitates the transfer of voice and multimedia over the Internet Protocol through Internet. IP security defines the set of protocols to secure the communication between two end points. The ESP provides various features such as encryption, data integrity validation and authentication payload. The security association defines the shared security attributes and ensures the secure communication between two network entities.

6.10 SOLUTIONS/ANSWERS

☞ **Check Your Progress – 1**

1. Mobile IP
2. Home Agent
3. Corresponding Node
4. Home Network

5. Care of Address
6. Tunnel

☞ **Check Your Progress – 2**

1. Time to live
2. GRE Header
3. Mobile binding
4. Cellular IP
5. Voice Over IP (VoIP)
6. IP Security

6.11 FURTHER READINGS

References

Mobile Computing 3rd Edition by Raj Kamal - https://www.amazon.in/Mobile-Computing-Raj-Kamal/dp/0199455414

UNIT 7 MOBILE TRANSPORT LAYER

Structure

7.0 INTRODUCTION

Mobile devices provide many services to the end user such as email, messages, apps, navigation, online gaming, online trading and such. All the mobile apps that interact over the network is facilitated by the transport layer which manages the data transmission from source port to the destination port.

In this unit we describe the transport layer protocols such as TCP and UDP.

7.1 OBJECTIVES

After going through this unit, you should be able to

- understand key concepts of UDP and TCP,
- understand the main use cases for UDP and TCP,
- understand the concepts and use cases for Indirect TCP,
- understand the concepts and use cases for snooping TCP,
- understand the concepts and use cases for mobile TCP.

7.2 UDP AND TCP

User datagram protocol (UDP) and Transmission control protocol (TCP) are the main transmission protocols for data transmission.

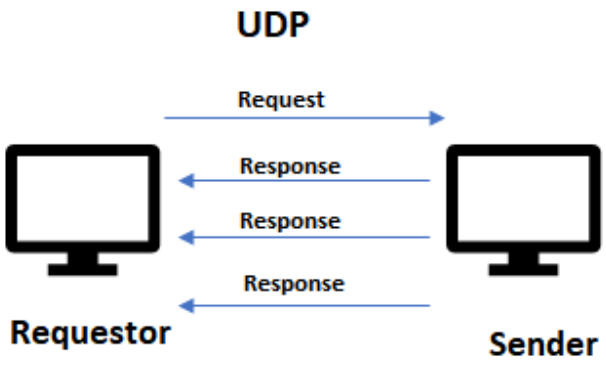
In this section we examine the key features, use cases and differences between UDP and TCP.

7.2.1 UDP

UDP is a connectionless transport layer protocol. UDP is used for faster transmission of data across two computers. It is unreliable as it does not wait for acknowledgement from the receiver. UDP also saves the bandwidth as it does not depend on the acknowledgement. Each of the UDP segments are handled individually and use independent paths to reach the destination.

UDP is faster as it starts transmitting the data packets (called datagrams) to the target computer without waiting for the handshake and acknowledgement. This process makes the UDP faster but unreliable.

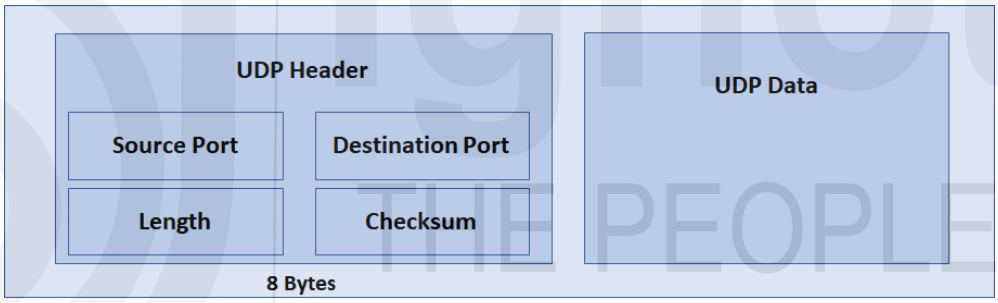
We have depicted the UDP data transmission in Figure 1.



As depicted in Figure 1, the requestor sends the request and sender sends the response data continuously. As the missed datagrams are not re-transmitted, the requestor has to devise methods to handle the data loss or duplicate data.

UDP Packet

We have depicted a UDP packet in Figure 2. The UDP header is 8 bytes long and has following details –



- Source Port provides details of source port in 16-bit field.
- Destination Port provides details of destination port in 16-bit field.
- Length provides length of the UPD in 16-bit field.
- Checksum provides metadata of header and UDP data and is used for checking data integrity.

UDP Scenarios

Given below are the use cases and scenarios where UDP is used –

- The time sensitive applications such as video streaming apps (such as video broadcast applications), audio streaming apps, Voice Over IP (VoIP), live conference, screen sharing applications, and others rely on UDP as the minor data loss is acceptable in such scenarios.
- High speed, low latency applications such as online gaming applications use UDP.

- DNS servers rely on UDP for faster data transmission.
- DHCP (Dynamic Host Configuration Protocol), NTP, DNS use UDP protocol.
- Real time application such as stock ticker application also uses UDP
- Multi-cast application such as trading platforms use UDP.

Risks

UDP can also be exploited by hackers for Denial of service (DoS) attack wherein they flood the target computers to exhaust its resources.

7.2.2 TCP

Transmission Control Protocol (TCP) is a connection oriented, full-duplex data transmission protocol that provides assured delivery, reliability. As TCP is connection oriented, the connection between the sender and receiver has to be established prior to the data transmission. TCP breaks down the message in various packets and sends them to the destination. TCP ensures the correct ordering of the data and identifies each machine on the network with a unique IP address. TCP guarantees the delivery of the packets. In the Open Systems Interconnection (OSI) model, TCP covers the layer 4, transport layer and layer 5, session layer.

We have given the detailed steps of how TCP works in transmitting the data –

1. TCP segregates the data into various packets and provides a sequence number to the packets.
2. TCP transmits these packets to the destination.
3. At the destination, the packets are re-assembled based on the sequence number and transmits it further. TCP acknowledges the arrived packets.
4. TCP handles re-transmission of the lost packets, dropped packets or garbled packets to provide error-free transmission.

We have depicted the TCP handshake in Figure 3. Post passive open the active open connection involves three-way handshake –

1. The client sends its data segment with the sequence number (for instance A).
2. The server then sends its sequence number with the acknowledgement. (for instance A+1)
3. Once the client receives the acknowledgement for its segment, the client sends the acknowledgement to the server.

TCP specifies the order in which the data packets need to be sent. If any of the packets are missed out, then TCP requests for the packet to be resent and hence it is more reliable than UDP.

Features of TCP

Given below are the main features of TCP –

- Segment number – All the transmitted or received segments are tracked by TCP using segment numbers.
- Flow control – The data transfer rate of the sender is controlled by flow control. The receiver uses sliding window to specify the data transfer for the reliable delivery.
- Error control – Each of the transferred segments are checked for errors to ensure reliable delivery. Duplicate segments, lost segment or out of order segments are detected using error control.
- Congestion control – TCP considers the network congestion during routing. TCP eliminates the network congestion using congestion avoidance algorithms such as Slow Start, Timeout React, Additive increase, Multiplicative Decrease and such.

TCP Packet Structure

We have depicted the TCP packet structure in Figure 1

<table>
<tr><th colspan="10">TCP Header</th><th>Data</th></tr>
<tr><td colspan="5">Source port Address (2 bytes)</td><td colspan="5">Destination port Address (2 bytes)</td><td></td></tr>
<tr><td colspan="9">Sequence Number (4 bytes)</td><td></td><td></td></tr>
<tr><td colspan="9">Acknowledgement Number (4 bytes)</td><td></td><td></td></tr>
<tr><td>HLEN (4 bits)</td><td colspan="2">Reserved (4 bits)</td><td>URG</td><td>ACK</td><td>PSH</td><td>RST</td><td>SYN</td><td>FIN</td><td>Window size (2 bytes)</td><td></td></tr>
<tr><td colspan="5">Checksum (2 bytes)</td><td colspan="5">Urgent Pointer (2 bytes)</td><td></td></tr>
<tr><td colspan="10">Options and Padding</td><td></td></tr>
</table>

Figure 1 TCP Packet Structure

The TCP header has following details –

- Source port address provides the address of the source port that sends the data.
- Destination port address provides the address of the destination port that receives the data.
- Sequence number specifies the sequence of the data bytes for a specific session.
- Acknowledgement number specifies the next sequence number by the receiver. For instance when the receiver receives the data with sequence number ‘A’, then the receiver responds with ‘A+1’ as the acknowledgement number.

- HLEN specifies the header length.
- URG, ACK, PSH, RST, SYN, FIN are the six control flags that control the connection and data transmission.
- Window size specifies the data size that receiver can accept. It is used in flow control.
- Checksum is the mandatory field for TCP and is used for error checking of TCP header, TCP payload and IP pseudo-header.
- Urgent pointer indicates the last urgent data byte.

TCP scenarios

TCP is used for use cases that require secure and reliable data transmission. Given below are the ideal TCP use cases and workload scenarios –

- Secure shell (SSH) for doing remote secure login
- File transfer protocol (FTP) for securely and reliably transferring the files
- Simple mail transfer protocol (SMTP) for sending out emails
- HTTP/HTTPS for viewing web data securely.

Differences between TCP and UDP

The table 1 provides the key differences between TCP and UDP

	TCP	**UDP**
Reliability	Reliable due to the handshake, acknowledgement, retransmission and timeout.	Unreliable as there is no acknowledgement, retransmission and timeout.
Message ordering	Messages are ordered	The delivery message order is not guaranteed.
Bandwidth requirement	Heavyweight as TCP needs three packets to setup the connection	Lightweight as there is no acknowledgement or ordering
Broadcast and multicast	Not supported	Supported
Speed	Relatively slow due to three-way handshake	Faster

☞ Check Your Progress 1

1. ____ is a connectionless transport layer protocol.
2. UDP header consists of _____ .
3. Streaming applications use _____ protocol.
4. When the data packets are lost or garbled, TCP performs _____.
5. In TCP, the transmitted or received segments are tracked by _____
6. _____ is used for error checking in TCP header.

7.3 INDIRECT TCP

Traditional TCP does not perform well on the wireless network. In addition to that we cannot change a TCP within a fixed network. Indirect TCP addresses these two issues.

Indirect TCP segments the TCP connection into wireless and fixed parts as depicted in figure 2.

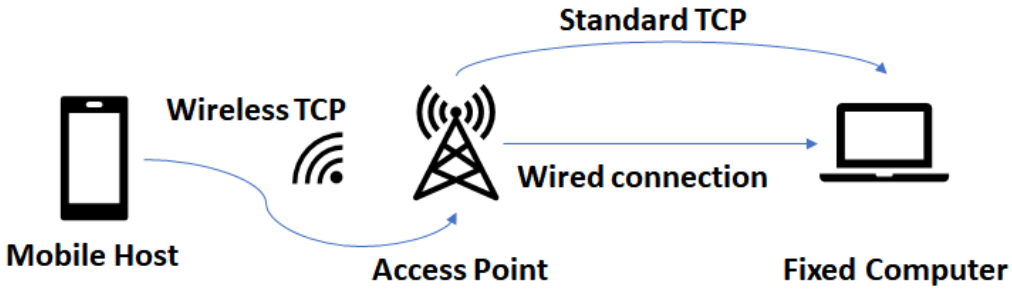


Figure 2 Indirect TCP

Given below are the salient features of the Indirect TCP as depicted in Figure 2 –

- The mobile host is connected via wireless TCP to access point and access point is connected through wired connection to the host.
- The access point is also connected to the fixed computer through standard TCP as well. The fixed computer acts as corresponding host.
- The access point terminates the standard TCP and acts as proxy for fixed computer to the mobile host. The access point relays information in both the directions (from mobile host to the fixed computer and from the fixed computer to the mobile host.)
- The connection is segmented at access point.
- The access point manages the mobility of the mobile device. It hands over the mobile host to the next access point when the mobile host changes location.
- The fixed computer is not aware of the segmentation as the access point acts as a proxy.
- When the fixed computer sends the data packet, the access point acknowledges it and relays it to the mobile host. The mobile host sends the acknowledgement which is received by the access point.
- If the data packet is lost between mobile host and the access point, the access point retransmits the packet (when it does not receive the acknowledgement from the mobile host).
- When the mobile host sends the data packet to the access point the access point sends the acknowledgement to the mobile host. When a transmission error happens, the mobile host notices it and resends the packet.
- The access point forwards the data packet to the fixed computer through the wired network. Any transmission errors in this delivery is handled by the access point.

During the handover of the mobile host from one access point to another, the state (sequence number, acknowledgement and others) is migrated to the new access point. The fixed computer does not see any changes. We have depicted the process in figure 3.

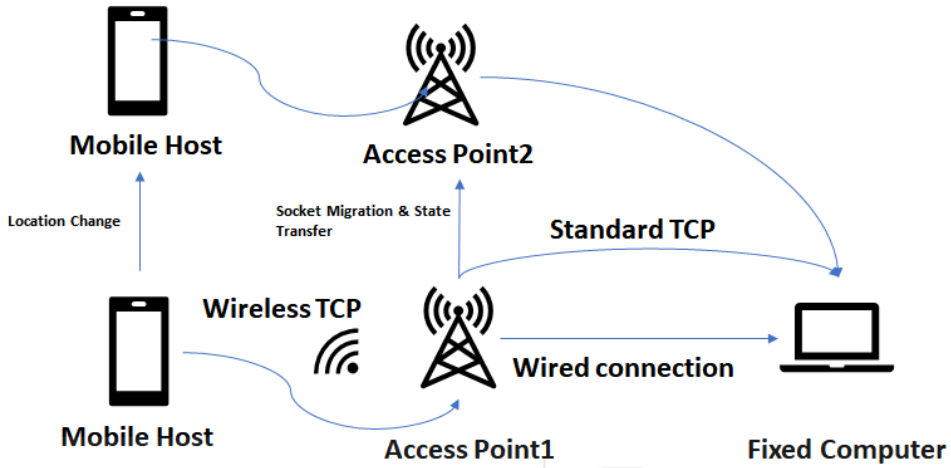


Figure 3 Location change of mobile host

Advantages of Indirect TCP

Given below are the main advantages of indirect TCP –

- The corresponding host (fixed computer) is abstracted from the changes to the mobile host and hence can work seamlessly.
- The indirect TCP is easy to manage and control as there is a single hop between mobile host and the access point.
- The indirect TCP is fault tolerant as the transmission error between mobile host and the access point does not propagate to the wired connection. When the transmission error happens between mobile host and the access point, the mobile host detects it quickly and retransmits the packet.
- Existing TCP protocol can be used without any changes.

7.4 SNOOPING TCP

One of the main challenges with the indirect TCP is that the TCP connection is segmented in the end to end network. As the mobile host uses wireless connection to access point and then access point uses wired connection to the fixed computer, the end to end TCP semantics is impacted.

The snooping TCP that enhances the TCP maintains the end to end TCP connection intact. Snooping TCP buffers the data at the access point and retransmits the data during the packet loss. We have depicted the snooping TCP in Figure 4.

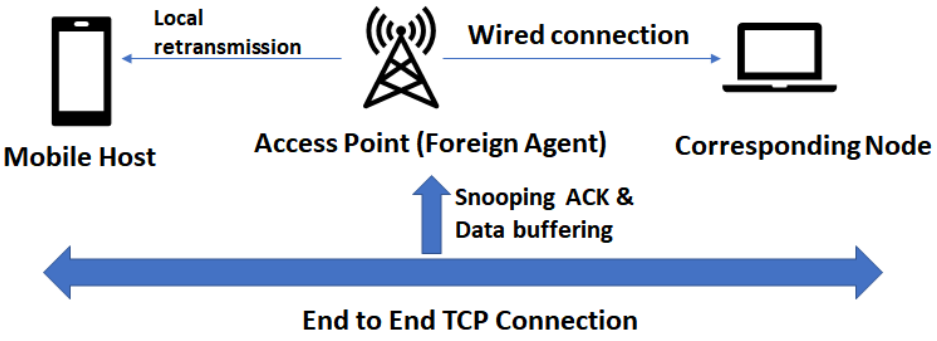


Figure 4 Snooping TCP

Given below are the steps of snooping TCP –

- The access point (foreign agent) buffers all the data that needs to be sent to the mobile host.
- The access point also snoops the acknowledgments and data packet flow in both the directions.
- The access point buffers each data packet till an acknowledgement is received.
- If the access point does not receive the acknowledgement from the mobile host, it retransmits the data packet from the buffer. The buffering improves the data transmission performance as compared to the retransmission from the corresponding node.
- The access point does not acknowledge the transmission to the corresponding node but filters the duplicate acknowledgements to avoid the duplicate data transmission from the corresponding node.
- In case of failure of access point, the corresponding node triggers the data packet retransmission when the access point times out.

When the mobile host transmits the data to the corresponding node, the flow is as follows :

The access point snoops the packets transmitted from the mobile host.

- If the sequence number is not correct or if any of the data packets is missing, the access point sends negative acknowledgement to the mobile host.
- The mobile host then retransmits the missing packets
- The packets are ordered at the fixed computer by TCP.

Snooping TCP advantages

Given below are the main advantages of the snooping TCP –

- The end to end TCP connection is preserved.
- The access point transparently handles migration of mobile to the new location.
- The enhancements can be transparently handled at the access point level.
- The timeout of access point is handled by the corresponding node.

7.5 MOBILE TCP

The mobile TCP aims to make the window size to zero and handle the mobile host getting disconnected. Mobile TCP targets to improve the overall throughput and reduce the overall latency and to provide efficient handover while maintaining the end to end TCP semantics. Mobile TCP also addresses the problem with lengthy disconnections.

Mobile TCP splits the traffic into two parts. The standard TCP is used for connection between supervisory host and the corresponding node. The optimized TCP is used between mobile host and the supervisory host. In the mobile TCP the supervisory host assumes the role of a proxy in the Indirect TCP by transmitting the data on both the ends. We have depicted the mobile TCP in Figure 5.

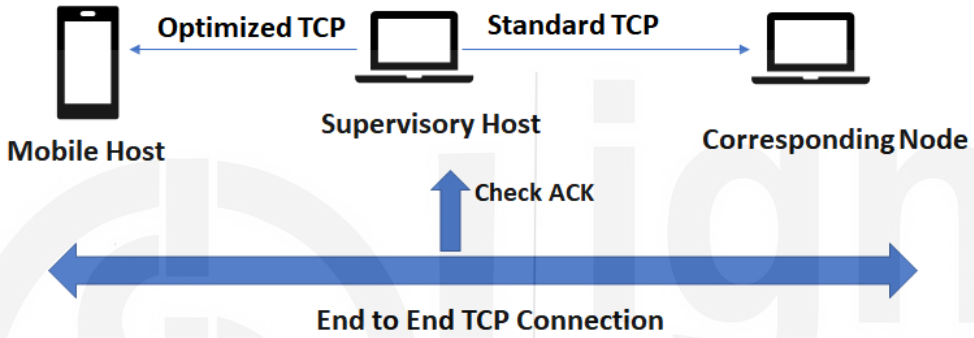


Figure 5 Mobile TCP

The steps of the mobile TCP are as follows -

- As the wireless link has low bit error rate, the supervisory host does not cache or buffer the data.
- When the packet is lost during transmission to the mobile host, the corresponding node has to retransmit the data packet.
- The supervisory host monitors the packets sent to the mobile host. The supervisory host forwards the acknowledgements to the mobile host.
- If the supervisory host does not receive an acknowledgement from the mobile host, it is assumed that mobile host is disconnected.
- The supervisory host sets the corresponding node's window size to 0 to make the sender go into persistent state. This ensures that sender's state will not change even though the mobile host is disconnected for extended duration.
- In the persistent state, the sender will not retransmit the data when the mobile host is disconnected for extended duration.
- When the mobile host becomes active, the supervisory host reopens the window and sets it to the old value of the corresponding node.
- The corresponding node can start transmitting the data to the mobile host.
- The mobile host uses optimized TCP to recover from packet loss quickly.

Advantages of mobile TCP

Given below are the main advantages of mobile TCP –

- The mobile TCP maintains the end to end TCP semantics as the supervisory host does not send any acknowledgement itself but forwards the acknowledgement to the mobile host.
- When the mobile host is disconnected, the mobile TCP eliminates unnecessary data retransmissions by setting the sender's window to 0.
- As the supervisory host does not buffer any data, there is no need to migrate the buffer data to the new supervisory host.

7.6 SUMMARY

UDP is a connectionless transport layer protocol. UDP is unreliable as it does not wait for acknowledgements and is used for faster transmission of data. In UDP, the requestor sends the request and sender sends the response data continuously. UDP header consists of source port, destination port, length and checksum. Streaming, low latency applications, multicast, DNS servers, DHCP are use cases for UDP. Transmission Control Protocol (TCP) is a connection oriented, full-duplex data transmission protocol that provides assured delivery, reliability. TCP handles re-transmission of the lost packets, dropped packets or garbled packets to provide error-free transmission. The three-way handshake of TCP involves Syn, Syn ack and ack. Segment number, flow control, error control, congestion control are key advantages of TCP. TCP header consists of Source port address, destination port address, sequence number, acknowledgement number, HLEN, control flags, window size, checksum and urgent pointer. SSH, File transfer protocol (FTP), SMTP, HTTP are main scenarios for TCP. Indirect TCP segments the TCP connection into wireless and fixed parts. The snooping TCP that enhances the TCP maintains the end to end TCP connection intact. Snooping TCP buffers the data at the access point and retransmits the data during the packet loss. In snooping TCP, the access point snoops the acknowledgments and data packet flow in both the directions. The mobile TCP aims to make the window size to zero and handle the mobile host getting disconnected. Mobile TCP splits the traffic into two parts. The standard TCP is used for connection between supervisory host and the corresponding node.

☞ **Check Your Progress 2**

1. Indirect TCP segments the TCP connection into _____
2. Mobile host is connected to the access point through _____ in indirect TCP.
3. _____ acts as proxy in indirect TCP.
4. In the snooping TCP, the data is _____ at access point which is retransmitted during packet loss.
5. In the mobile TCP, _____ is used between mobile host and the supervisory host.

7.7 SOLUTIONS/ANSWERS

Check Your Progress 1

1. UDP

2. source port, destination port, length and checksum
3. UDP
4. packet retransmission
5. segment numbers
6. checksum

Check Your Progress 2

1. wireless and fixed parts
2. wireless TCP
3. Access point
4. Buffered
5. optimized TCP

7.8 FURTHER READINGS

References

Mobile Computing 3rd Edition by Raj Kamal - https://www.amazon.in/Mobile-Computing-Raj-Kamal/dp/0199455414

UNIT 8 DATABASE MANAGEMENT ISSUES IN MOBILE COMPUTING

8.0 INTRODUCTION

We store the business data in a database management system. With the explosion of various devices and increase in users' access to the Internet, the data volume has exploded in the recent past. The application stores the core application data, configuration data, transaction data and other business data in the database system. Few applications also store the log data and audit data in the database.

As mobile has become the primary gateway for Internet access, the importance of mobile database has grown exponentially. Modern application architectures use offline-first approach where mobile applications store the data in the local database on the device for providing enhanced user experience during network issues. Mobile applications also use device database for storing the user profile data, cached data, configuration data and other details.

Normally the data is stored in files or in memory cache or in the database. For instance, a mobile device stores the pictures in the local device folder in the file format. As mobile devices are not always connected to the network we need to ensure that data is available in the offline mode.

In this unit we shall examine the key database management issues in the mobile computing

8.1 OBJECTIVES

After going through this unit, you should be able to

- understand key concepts of database,
- understand various types of databases,
- understand the issues with mobile data management,
- understand various data store methods for mobile,
- understand the client server computing for mobile computing, and
- understand adaptation software for mobile computing.

8.2 MOBILE DEVICE DATABASE MANAGEMENT

In this section we discuss the brief details of database management for the mobile computing.

8.2.1 Brief Details about database management system

A database management system is used for organizing information that can be easily persisted, queried and managed.
Based on the nature of the data, we can leverage various kinds of databases. Data is organized in structured way to easily persist and retrieve in relational database systems. In No-SQL databases we mainly store the key-value pairs, or documents or graph-based data or unstructured data.

Each data record is organized as a database row. We store the entity data in a database table. The properties of the entity are managed as attributes. Lets consider a simple example of representing the student entity in the database table

StudentId	StudentName	StudentPhone	StudentAddress
123	Student1	1231231234	Bangalore
456	Student2	1234123456	Delhi

In the above example we have depicted various attributes of student entity such as studentid, studentname, studentphone and studentaddress. We also have two rows representing two data records.

We can perform various operations on the data stored in the database. We have given the key operations:

- Query operation – we can query the structured data from the database table. We can also filter the data using a conditional operator.
- Insert operation – We can insert the data into the specific table using the insert operation.
- Delete operation – We can delete a row(s) from the database based on the condition.

A database transaction consists of series of database operations (for example insert operation followed by delete operation). The database ensures the consistency and data integrity of the transaction.

We can establish a foreign key relationship with other tables when two entities are related. For instance, lets consider a course table as below

CourseId	CourseName
1	Computer Science
2	Electronics & Communication

If we need to associate the students to the courses, we can introduce a foreign key to the Students table as shown below

StudentId	StudentName	StudentPhone	StudentAddress	CourseId
123	Student1	1231231234	Bangalore	1
456	Student2	1234123456	Delhi	2

We have now introduced the CourseId foreign key to the student table. We can associate the student to a course using the foreign key. We can filter the data to using the foreign keys; for instance in the students table we can query all the students who have taken up Computer Science course by joining the Students table with Courses table and matching the CourseId.

Types of databases

There are various kinds of databases. We can use the most appropriate database based on the use case. Given below are the some of the most popular databases

- Relational database: The data is stored in tables which are related to each other. For structured data use cases such as financial data we use relational database. MySQL, Oracle, MS SQL Server are some of the popular relational database systems.
- No SQL database: The database schema/model is flexible in No SQL database. We can store the session data, shopping card data in No SQL database. MongoDB, DocumentDB are few examples of No SQL database engines.
- XML Database: We use the XML tags as the keys in the XML database. We can use the XML database to manage the key value pair use cases.

Mobile database management systems

SQL Anywhere mobile device database, IBM DB2 Everyplace, Oracle 9i Lite, Microsoft SQL compact, SQLLite are some of the popular mobile device databases. All mobile database systems use small memory footprint due to the limited resource availability on mobile devices. Mobile devices can store the application configuration, user preferences, user profile and other offline data in the local database.

Explicit business logic and Implicit business logic

The mobile apps use APIs to interact with the database. When the business logic is explicitly specified in the API, it is termed as explicit business logic. For instance, in an ecommerce application when we would like to display a product details page for a specific product we send the product id as a filter parameter such as follows:

If product_id=1234 and geography="India" then Get_product_details

The above logic filters the data explicitly based on the product_id and geography.

In an implicit business logic, the structure of the database is used to retrieve the data from the database. For instance when you search for a contact name in the

contact list, the mobile app automatically shows the phone number associated with the contact. The association of phone number for the contact is implicit.

☞ Check Your Progress 1

1. Key value pairs are stored in ____ database
2. Series of database operations that ensure consistency is called _____
3. When the business logic is specified in the API it is called _____ business logic
4. In an _____ business logic, the structure of the database is used to retrieve the data from the database

8.3 Mobile Device Data Store Methods

Mobile devices have limited storage capacity. We cannot store large quantities of data on mobile devices. For dynamic mobile apps we need to retrieve the data from the server. If the mobile device tries to retrieve large quantity of data for every screen refresh, it impacts the end user experience.

Hence to balance the dynamic nature of the data and the mobile app performance, the mobile app needs to store the data locally on the device. Storing the frequently used data locally on the device is referred to as caching or hoarding.

Normally the mobile device caches the data fetched from the remote server. For subsequent calls, the mobile device uses the locally cached data; the mobile app uses the locally cached data during the absence of network. The mobile device cache is refreshed when the mobile is connected to the network. For instance, a learning mobile app that teaches the vocabulary caches the most frequently used words in the local device cache. When the device connects to the Internet it refreshes the data.

We shall look main architecture patterns for mobile device data store methods.

Single Tier Architecture

In this architecture model, the mobile app directly interacts with the embedded database on the mobile device. We could use embedded mobile database such as SQLLite which stores the frequently access mobile app data. The embedded mobile database stores the core application data such as business data, location data, user data that enables the mobile app to be operated in the offline mode as well.

Figure 1 depicts the single tier architecture database

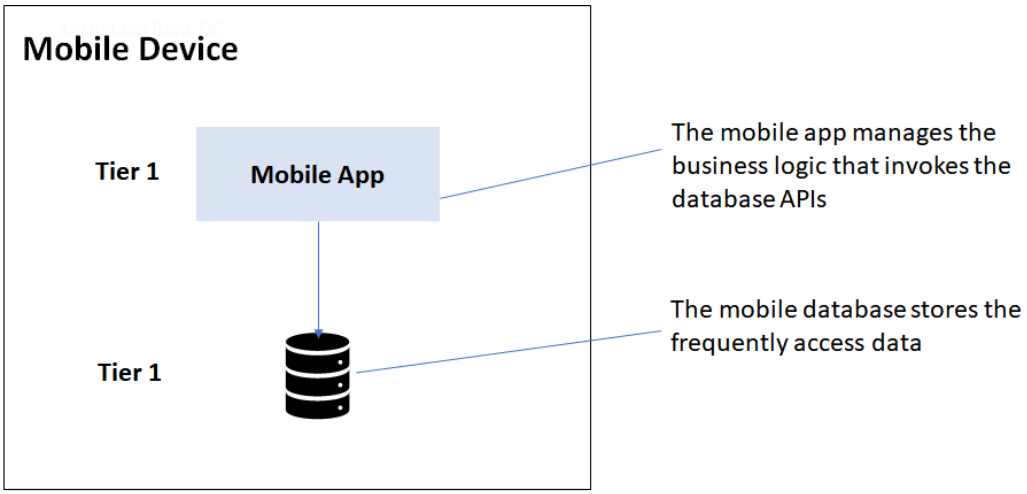


Figure 1 Single Tier Mobile database architecture

In single tier mobile database architecture, the entire mobile app data is hoarded within mobile device.

Multi-Tier Architecture

In a typical multi-tier architecture, the mobile app uses the data stored in the remote database through APIs. Figure 2 depicts a multi-tier architecture. The mobile app in tier 1 invokes the business services in tier 2 which gets the data from the database in tier 3.

The mobile app can optionally cache the retrieved data locally in a cache or a database. This reduces the overall latency in invoking the data from the remote database. We have depicted the local caching architecture in Figure 3.

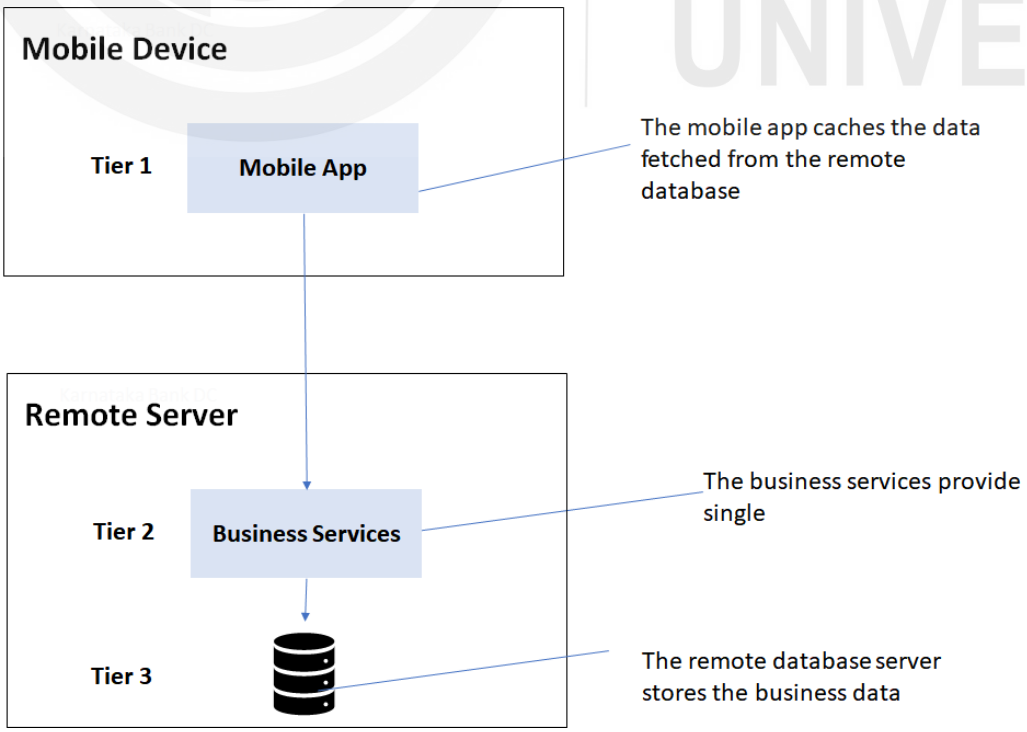


Figure 2 Multi-tier Mobile Database Architecture

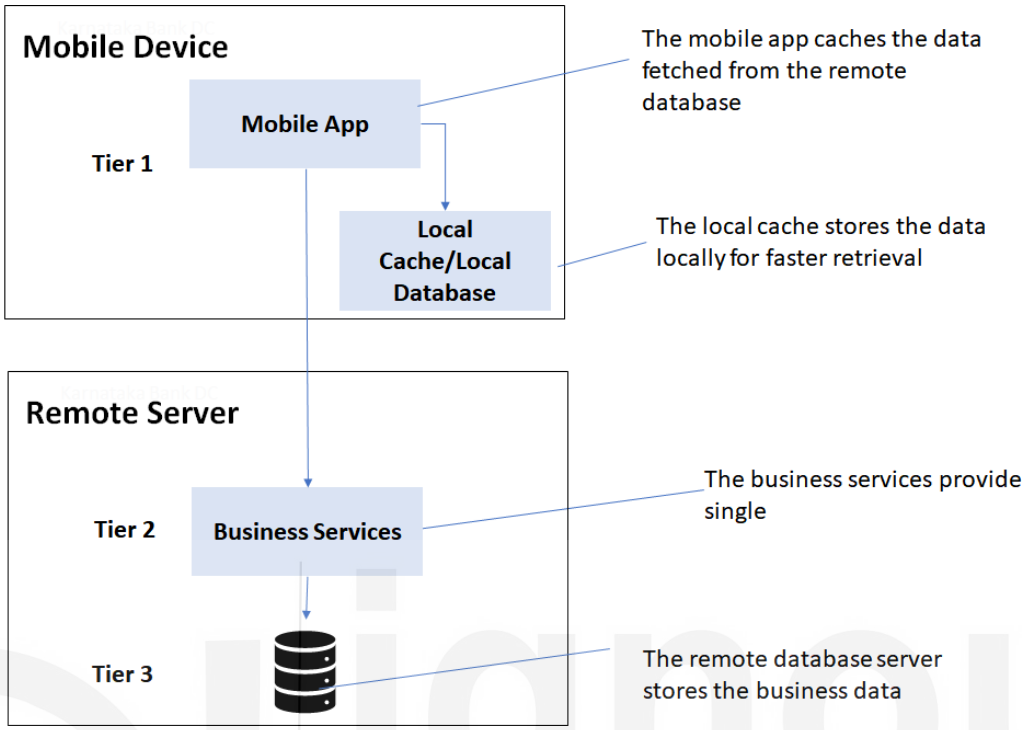


Figure 3 Multi-tier Mobile Database Architecture With Local Caching

The local cache in Figure 3 periodically synchronizes the data from the remote server so that the mobile app can invoke the data faster.

We have depicted a n-tier architecture in Figure 4. We have depicted various SDKs that will be integrated with the mobile app. We also have depicted various functional modules such as login module, products module, home screen module and such.

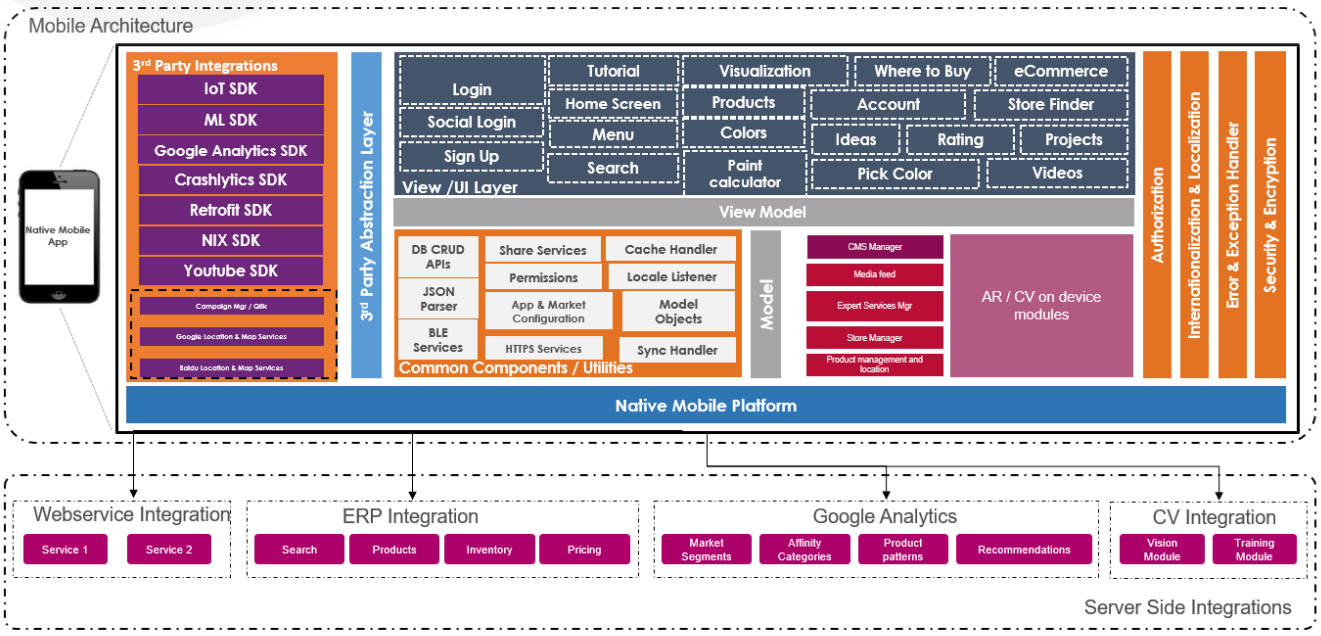


Figure 4 Multi-tier Architecture for an enterprise mobile app

The main integrations for the enterprise mobile app are ERP, Google analytics, web services and OpenCV. All these applications are integrated through APIs.

Caching Patterns

In the multi-tier architecture the mobile app caches the data to reduce the overall latency. The general thumb rule for the data to be cached is the access probability of the cached data. If the data is regularly accessed (for instance user detail information or static information that is displayed on each mobile screen) then it is an ideal cache candidate.

Broadly there are two methods to populate the cache. In the first method the mobile app pulls the required data from the remote server and caches that data. The mobile app can pull the most frequently used data to reduce the overall latency. The second one is the push method where the server pushes the data. The push is mainly used by the server to synchronize the server data with the client data. Among the push and pull methods, the pull method is optimal as only the required data is pulled when it is required.

We have depicted the pull pattern of caching in Figure 5 where the mobile client pulls the cached content from the systems.

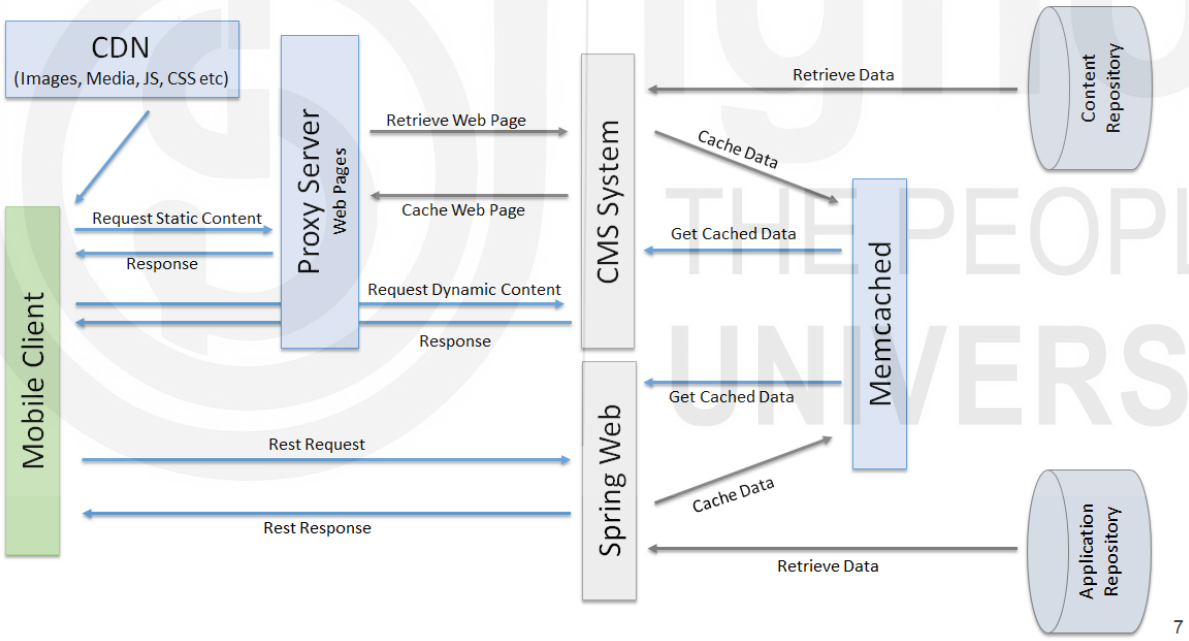


Figure 5 Pull pattern of caching

Another caching technique is the pre-fetch wherein the mobile app prefetches the data in advance in anticipation of its need. For instance if the mobile user has visited the product list page, the mobile app can prefetch the product details in anticipation of mobile user visiting the product details page.

When the mobile app does not find the required data in the local cache it is called “cache miss” and the mobile app has to go back to the server to get the required data.

We need to use appropriate cache invalidation mechanism to ensure that the mobile client gets the accurate data. There are broadly four cache invalidation methods:

- Stateless asynchronous in which a broadcast message invalidates all cached objects of all clients of the server
- Stateless synchronous in which the server broadcasts the cache invalidation method when the data is change or modified.
- Stateful asynchronous where the server broadcasts the cache invalidation message only for the specific clients who are impacted. The server does not keep track of the client data
- Stateful synchronous where the server keeps track of the client data and broadcasts cache invalidation message to the specific client when the data is changed.

8.4 Client Server Computing with Adaptation for Mobile Computing

In the evolution of the enterprise architectures we initially had mainframes. In the next stage we had client server architecture. In client-server architecture, the heavy computing and memory resources are deployed in the server. The server handles the core business computing and data processing. The clients have lesser resource capacity and they simply connect to the servers to retrieve the data or submit the job. Terminal applications and database clients, thick clients mainly used the client-server architecture.

In the mobile computing, the mobile apps are equivalent to the client applications. As mobile devices have limited resources such as memory, storage they retrieve the data from the servers. We have depicted a 4-tier architecture in Figure 6 where mobile is the client application

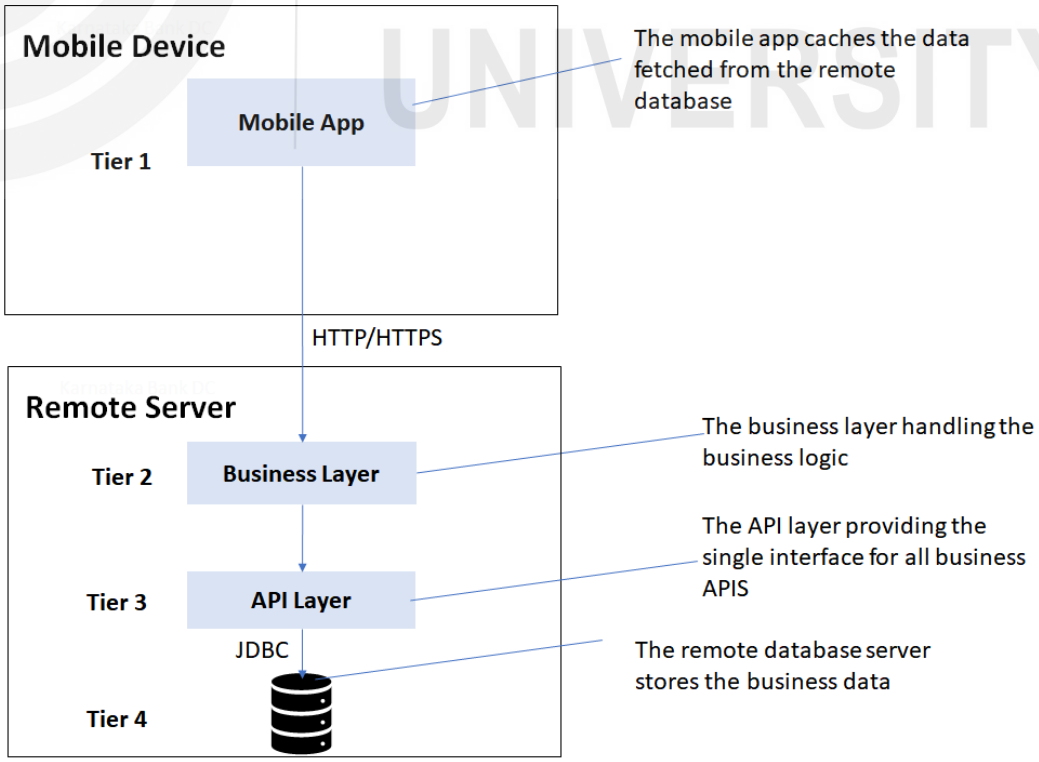


Figure 6 Four-tier mobile computing architecture

The 4-tier architecture depicted in Figure 4, the mobile app interacts with the business layer through HTTP or HTTPS. The mobile app invokes the business services through modern architecture patterns such as REST over HTTP. The business layer centralizes the business logic processing and uses the appropriate APIs in the API layer. The API layer is the single interface for all backend integrations. The API layer provides APIs to retrieve the data from enterprise database, from web services and from ERP services. To retrieve the data from enterprise database, the API layer uses JDBC calls. The enterprise data is stored in the centralized enterprise database. In the 4-tier architecture, the mobile app can also cache or hoard the data locally to improve the performance. The local cache or database on the mobile device synchronizes with the remote server using synchronization server.

In a typical n-tier architecture each layer has distinct responsibilities and handle single concern. This architecture design is called "separation of concerns" and "Single responsibility principle" These principles helps in building the decoupled architecture where each layer can be scaled independently.

8.5 Adaptation Software for Mobile Computing

The mobile device uses multiple interface such as email, contacts, calendar and others. As the data format sent by the synchronization server is different from the data structure expected by the database, we need an adaptor that converts the data format of the synchronization server to that of the database.

The adaptors convert the data from the standard format into the format needed for the APIs and interfaces.

We have depicted the adaptation software in Figure 7.

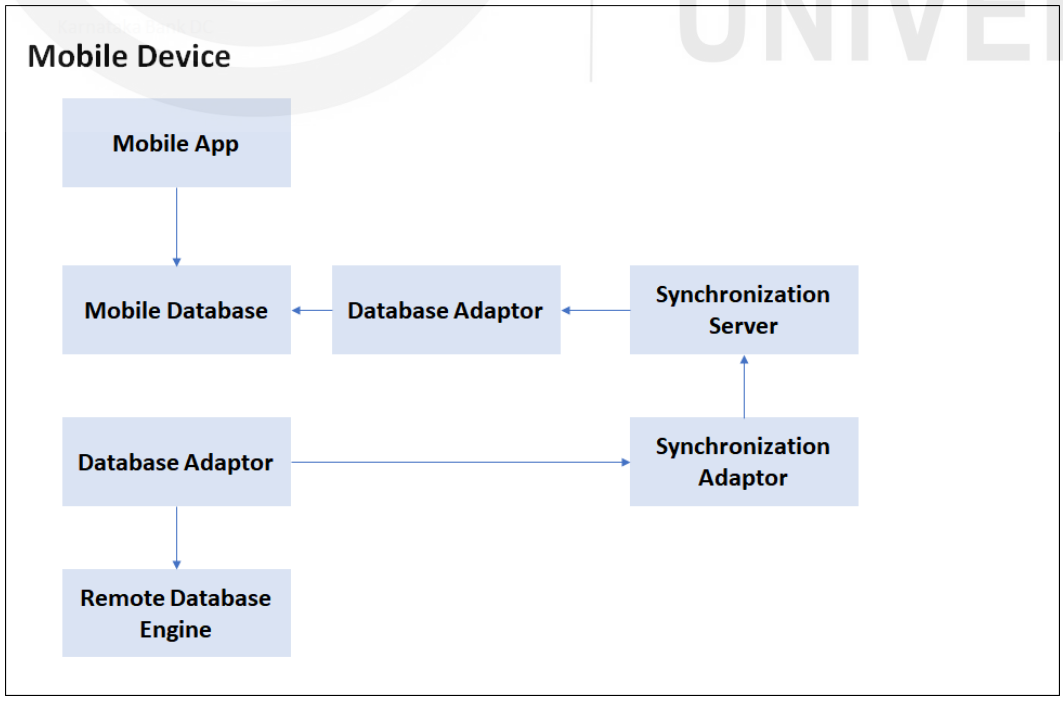


Figure 7 Adaptors at mobile device

As shown in Figure 6, we mainly need two adaptors. The first adaptor that converts the data received from the synchronization server to the mobile database. This database adaptor is present in the mobile end.
The second adaptor is at the remote server which converts the data from the remote database to the synchronization data.

☞ Check Your Progress 2

1. In single tier architecture, mobile app interacts with the embedded database ____
2. In multi tier architecture, the mobile app invokes the data stored _____ through APIs
3. In _____ method of caching, the server sends data to be cached to the client
4. The caching method in which the client requests for the data to be cached is called _____ method
5. In _____ method of cache invalidation all the clients receive a cache invalidation broadcast.

8.6 SUMMARY

In this unit, we started discussing the core concepts of the database. In SQL databases the data is managed in a structured schema. Key values are stored in NoSQL databases. In single tier architecture for mobile computing, the mobile app directly retrieves the data from the embedded database. In the multi-tier architecture, the mobile app retrieves the data stored in the remote database through APIs. Caching can be mainly done using push method wherein the server pushes the data to be cached to the client and pull method wherein the client pulls the data to be cached from the server. In a typical n-tier architecture in mobile computing the mobile app retrieves the data through APIs.

8.7 SOLUTIONS/ANSWERS

Check Your Progress 1

1. NoSQL
2. transaction
3. explicit
4. implicit

Check Your Progress 2

1. directly
2. remotely
3. push
4. pull
5. stateless asynchronous

8.8 FURTHER READINGS

References

Mobile Computing 3rd Edition by Raj Kamal -
https://www.amazon.in/Mobile-Computing-Raj-Kamal/dp/0199455414

UNIT 11 VIRTUAL AND CLOUD NETWORKS

Structure

11.0 INTRODUCTION

Wired and wireless network is by enterprises and end users for accessing information and for performing the tasks. Network enables users to access the required information faster and scale the information access to millions of users.

Mobile device is now all pervasive impacting the daily lives of billions of users. Mobile devices communicate with Internet and Intranet networks for accessing information and for user collaboration. Mobile devices also heavily use public cloud for storage, computing and for secured database.

In this unit we discuss various features of wireless enterprise networks, virtual networks and mobile cloud networks.

11.1 OBJECTIVES

After going through this unit, you should be able to

- understand key concepts of wireless enterprise networks,
- understand security of wireless enterprise networks,
- understand key concepts of virtual network,
- understand key concepts of mobile cloud network.

11.2 WIRELESS ENTERPRISE NETWORK

Enterprises such as banks, business corporates, manufacturing companies provide wired and wireless access to its data for its employees, partners and customers. Corporate employees access the data through intranet networks whereas users access the relevant data through corporate portals and web or mobile platforms.

The enterprise needs to provide secured access to its data meaning that users need to authenticate to access the private data. Post authentication, users should have suitable permissions to access the relevant content.

Enterprises use wide variety of servers, mainframes, firewalls network devices (such as routers), databases to manage and deploy the applications. The core APIs and services are built on top of the existing applications.

We have depicted a typical enterprise network component in Figure 1

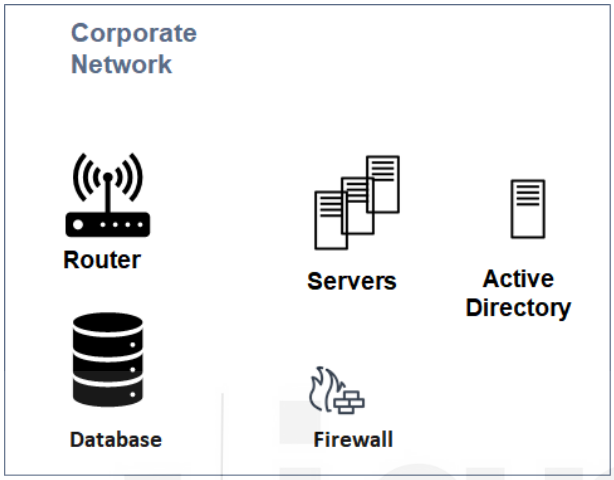


Figure 1 Corporate network components

Wireless enterprise networks provide secured access to the enterprise data and services wirelessly. For instance the employee access the corporate network wirelessly through the mobile apps (such as calendar, corporate email, corporate paging systems) is an example of wireless enterprise network.

Given below are few examples of enterprise applications that normally uses the enterprise wireless network –

- Enterprise Email mobile app
- Enterprise secured browser
- Enterprise calendar mobile app
- Enterprise Intranet portal accessible on mobile device
- Enterprise paging system
- Enterprise user onboarding mobile app

Essentially the mobile apps that access enterprise data and enterprise services use wireless networks.

11.2.1 Features of Wireless Enterprise Network

The wireless enterprise network should be robust to handle various enterprise scenarios. We have depicted various features of wireless enterprise network in Figure 1. The main features of wireless enterprise network can be categorized into five main categories – security, fine-grained access, resilience, scalability and perimeter security.

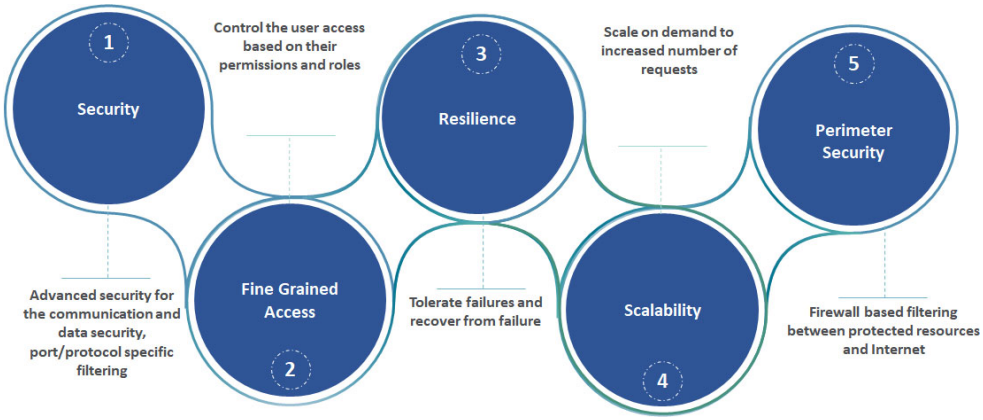


Figure 2 Features of wireless enterprise network

As the enterprise wireless networks provide the access to sensitive corporate information, the core feature of the wireless network is security. The wireless enterprise network should force the authentication for the users to access the sensitive information and allow only the specific protocols and ports. Secondly the wireless network should provide fine grained access based on the user groups and permissions. Thirdly the wireless enterprise network should be resilient and should tolerate and recover from the failures. Fourthly the enterprise wireless network should be scalable to handle a sudden spike in the requests. Lastly the enterprise wireless network should provide the perimeter security through perimeter firewall that filters the traffic between enterprise servers and the Internet.

Enterprises adopt layer-wise and defence-in-depth security model wherein the security policies are implemented at each level. At the enterprise server level, the application allows only the authenticated users. Post authentication, fine grained security is enforced wherein the enterprise authorizes the access to the specific business functionality based on the logged-in user's role and access level. Additionally, the application server logs all the key events (such as password change, login failure and such) to the log files. We also use middleware systems such as Mobile Device Management (MDM) systems that enforce security policies on the end user devices. The security policies enforce the security policies such as access location, device patch level and such.

11.2.2 Components of Wireless Enterprise Server

We have depicted various components of wireless enterprise network in Figure 3.

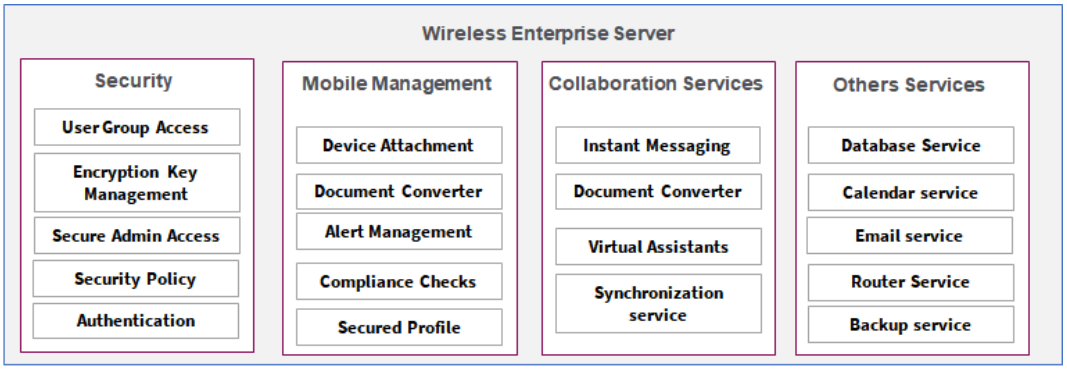


Figure 3 Wireless enterprise server components

We have grouped the components into various categories such as security, mobile management, collaboration services and other services.

In the security category, the wireless enterprise server provide user group and role based access to various services (such as configuration service, administration service and others). The server should also generate the encryption keys that are used for encryption and decryption. The enterprise server also defines various security policy(such as geo-location restriction) and provides the secured administration access. The security policy server pushes the security policies to the mobile devices.

As part of mobile device management (MDM), the enterprise server provides device attachment features wherein the enterprise users can securely register their mobile devices. As part of the device attachment, enterprise users have to provide mobile device details such as mobile OS and mobile identifier. MDM module defines the mobile device compliance rules (such as patch versions) and regularly performs the compliance checks such as mobile OS patch version. MDM also securely open the documents of various formats. MDM also supports other features such as remote wipe

The enterprise server also provides the collaboration service wherein an instant messaging software for users to collaborate among themselves. We could also leverage the connectors that can connect to various third party services such as web services or databases. The synchronization services synchronize the calendar and email on the end mobile devices. Virtual assistants provide chat bots service that users can use to get the information quickly.

The enterprise server provides various other services such as the following –

- Database service to store the user profile and user data
- Email service to manage the user emails
- Push notifications for the mobile device
- Alerts for the enterprise users
- Over the air backup and updates
- Router service to connect the mobile devices to the wireless network
- Backup service for data backup

☞ Check Your Progress 1

1. ___ feature of wireless enterprise network tolerates and handles failures.
2. As part of the _____, enterprise users have to provide mobile device details in Wireless enterprise server.
3. ____ handles the compliance check and remote wiping in Wireless enterprise server.
4. _____ handles the instant messaging in Wireless enterprise server.

11.3 VIRTUAL NETWORK

Networks establish connections among devices, users and domains. Networks also helps us to share information, resources and communicate with each other. Internet is one of the largest networks that allow billions of users and devices to exchange the information.

The physical network uses cables and wires to connect the networks and virtual network extends the features by using software to manage the routing, communication, security and such.

Virtual network is a software-based network that allow different domains or devices to connect to each other over physical network. The communication happens across virtual devices and routers through software-based network. The virtual networks use the same principles of physical network but with reduced operating and maintenance cost.

Enterprises can build virtual network spanning different data centers helping me to build more resilient, fault tolerant and make them more secure. Enterprises can also modify the security rules and network rules easily in the virtual network.

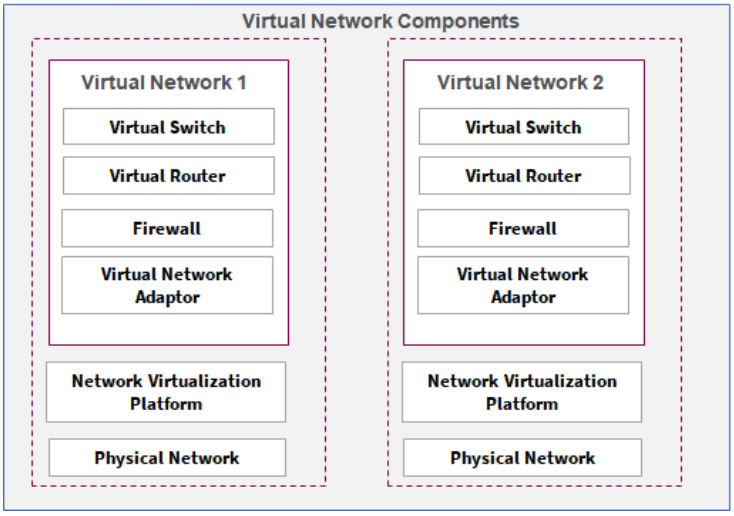
11.3.1 Parameters of Virtual Network

Given below are the parameters of the virtual network –

- Virtual switch – the virtual switch is setup on the host server and is responsible for routing the traffic between virtual network and the underlying physical network.
- Physical network – is the host for the virtual network
- Virtual network adaptor – is the gateway allowing all virtual machines to connect to the network. Using virtual network adaptor, the machines in the Local Areas Network (LAN) can connect to the network.
- Servers – host the server software and part of the virtual network
- Firewalls – monitor the network traffic and detect the threat and anomalous traffic in real time.
- Virtual machines – the machines that connect to the virtual network for exchanging the data

Machines running different operation system (such as Windows, Mac etc.) can do the remote connection using Virtual Network computing (VNC) platform. VNC platform enables the client and server machines to do the remote share of the desktop using the remote frame buffer (RFB) protocol.

We have depicted the parameters of the virtual network in Figure 3.



11.3.2 Types of Virtual Network

Given below are popular types of virtual network –

Virtual Private Network (VPN)

VPNs connect devices over Internet securely (for instance, using encrypted data over IPSec tunnels). VPN allows the home computers or on the go devices to security connect to the corporate Intranet. There are different types of VPN –

- Site to site VPN wherein we connect two networks using VPN that can be used to connect corporate office to all its branch office networks.
- Client VPN wherein a client device connects to the corporate network securely

Virtual Local Area Network (VLAN)

VLAN segregates the local area network (LAN) into different groups and broadcast domains using software for better security, monitoring and manageability. VLANs provide more control over the network traffic and devices. VLANs also helps in securing the data reliably.

11.3.3 Advantages of Virtual Network

Given below are the main advantages of virtual network –

- Virtual networks are the main elements of public cloud platforms that provide hyper scalability and high availability.
- Virtual networks helps in centralized, simpler, easier and flexible network management.
- Virtual networks reduce the cost due to the software based segregation.
- Virtual networks provide flexible network routing and configuration.
- Virtual networks provide fine-grained control on the network traffic.
- Virtual networks improve the overall productivity by helping the network administrators automate the setup.

11.4 MOBILE CLOUD NETWORKS

Modern smart phones are part of user's daily life managing various details such as call records, photos, calendar, notes, work related documents, appointments and such. Smart phones are increasingly used to manage huge volume of data. Due to the limited storage capacity of the mobile device, mobile devices leverage cloud computing to offload the storage and computing requirements.

Public cloud platforms are hyper scalar platforms that provide elastic scalability, unlimited storage, high availability and high resilience at lower cost. Public cloud platforms provide highly available network and infrastructure services. Most of the smart phones leverage multiple cloud services to provide seamless user experience.

In this section we shall examine the main cloud services that modern-day smart phones leverage

11.4.1 Cloud Storage Services

Leveraging the cloud storage service is one of the primary use cases for smart phones. As users heavily use smart phones to store photos, media files, the smart phones backup the photos, albums and media files to the cloud storage service for high durability and high availability.
One of the main examples is the cloud drive service offered by Android mobile devices. Users of Android mobile device can backup their media files into Google Drive. Similarly Apple iPhone users can backup their storage on Apple's iCloud services.
In addition to photos and media files, the mobile device also backups contact details, calendar, files, call history, app installation details to the cloud service.

11.4.2 Cloud Compute Services

Few use cases such as deep learning, augmented reality and Artificial intelligence need high compute capacity. For instance, identification of a pattern among the video frames, virtually painting the house with a different color and others need compute intensive machine learning models.

For such use cases, the smart phones send the photos and videos to the cloud services in real time and cloud compute services run the machine learning inferencing jobs and send the results back to the smart phone in real time.

11.4.3 Software as Service (SaaS)

Cloud infrastructure provides various software as service features such as serverless functions that can be used for various use cases such as photo editing service, language translation service, text editor service, messaging service and such. Mobile devices can leverage the SaaS for the use cases.

11.4.4 cLOUD based business applications

Mobile devices can also leverage various business applications such as email application, calendar application, screen sharing application, online meeting application that are hosted on the cloud platforms. The end users can subscribe to those services and use it for personal and business use cases.

11.4.5 Cloud Based Database

Mobile devices can also use the secure database on cloud to manage their sensitive data such as identity documents, contact list, web site passwords and such. The cloud platform uses various encryption algorithms to secure the information on cloud.

☞ Check Your Progress 2

1. Virtual network is a ____ network that allow different domains or devices to connect to each other.

2. _____ is responsible for routing the traffic between virtual network and the underlying physical network.

3. _____is the gateway allowing all virtual machines to connect to the network.

4. Deep learning use case leverage _____ services of cloud.

5. Email is an example of cloud based _____.

11.6 SUMMARY

In this unit we started by discussing the concept of wireless enterprise network. Applications such as email, calendar, Intranet portal use the enterprise wireless network. The main features of wireless enterprise network can be categorized into five main categories – security (secured communication), fine-grained access (role based access to service), resilience (recover from failure), scalability (on-demand scalability) and perimeter security (firewall based traffic filtering). The enterprise wireless server components can be grouped into various categories such as security, mobile management, collaboration services and other services. Virtual network is a software-based network that allow different domains or devices to connect to each other over physical network. Virtual network provides high scalabilty, greater flexibility, high availability with lower cost. The main parameters of virtual network are virtual switch, physical network, virtual network adaptor, servers, firewalls and virtual machines. The main types of virtual network are Virtual private network (VPN) and Virtual Local Area Network (VLAN). Mobile devices mainly use the storage, compute, Software as service, business applications and secured database of public cloud platforms.

11.7 SOLUTIONS/ANSWERS

Check Your Progress 1

1. resilience.
2. device attachment.
3. Mobile device management.
4. Collaboration service

Check Your Progress 2

1. software-based.
2. Virtual switch
3. Virtual network adaptor
4. Compute
5. business application

11.8 FURTHER READINGS

References

https://en.wikipedia.org/wiki/Network_virtualization

https://en.wikipedia.org/wiki/Cloud_computing

UNIT 12 MOBILITY, PORTABILITY, REPLICATION AND CLUSTERING

Structure

12.0 INTRODUCTION

Mobile devices are used for various use cases in our daily lives. We use mobile devices to chat with our friends, to take pictures, to send and receive emails, play games, navigate through maps, to attend online meetings and such. Modern day smart phones provide machine learning (ML) and artificial intelligence (AI) enabled features such as vison, image recognition, augmented reality and many other features. Customers, enterprises, businesses all use mobile apps to deliver information, services and to share resources.

The mobile device accesses the services over the Internet and uses enterprise applications, cloud databases and other services. To provide constant connectivity and data access mobile device has to be in constant touch with the access points.

In this chapter we discuss the mobile data management, data replication and adaptive clustering related to mobile device.

12.1 OBJECTIVES

After going through this unit, you should be able to

- understand key concepts of mobile data management,
- understand data replication schemes,
- understand key concepts of adaptive clustering

12.2 MOBILE DATA MANAGEMENT

Mobile devices manage the data required for its services and apps locally as well on remote secure cloud databases. The mobile data includes the contact list, photos, media files, conversations, documents, game data and such. Mobile device stores these files in local database and also regularly synchronizes the files with the remote database.

A mobile app might use the data that is distributed across various databases. For instance, a gaming mobile app might use the authentication service from the enterprise's active directory and it might use the cloud database to persist the game details (such as game levels, game points for a given user). Hence the mobile device has to process the queries for distributed databases. We have depicted a mobile computing system in Figure 1 that uses distributed services and database across cloud platform and corporate data center and business services.

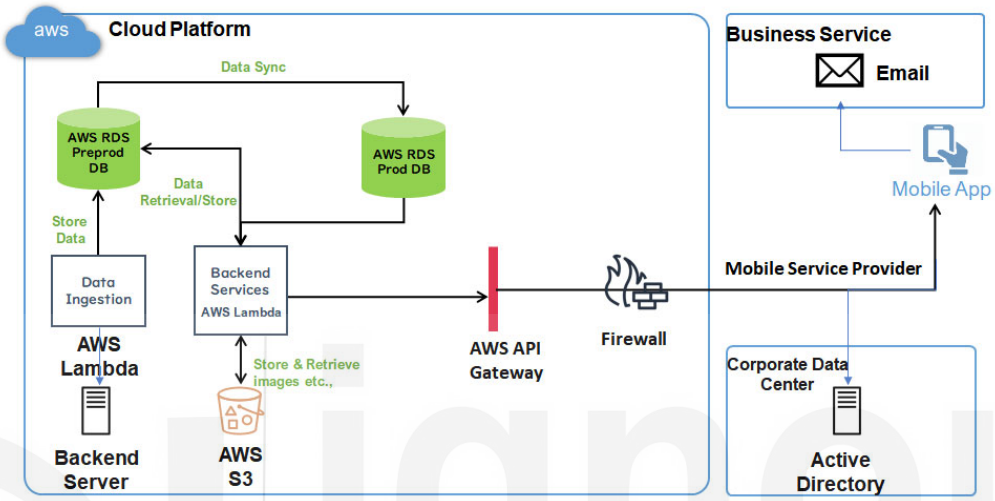


Figure 1 Mobile computing system that uses services distributed across cloud and data centre.

In Figure 1, the mobile app is connected over secured network to the cloud platform, corporate data center and business application that is exposed as software as service platform.

The mobile app provides shopping experience to the end user and connects to AWS (Amazon Web Service) cloud platform for backend processing. To start with, the shopping mobile app authenticates the user against the active directory hosted in the corporate data center. Once the user is successfully authenticated, the product details and user search results are fetched from the backend severs hosted in the AWS. The product list and product search APIs are hosted in the AWS API Gateway that internally uses the Lambda functions and backend servers to get the required information. The backend servers and the Lambda function retrieves the information from the AWS RDS database service. The mobile app users use the email service hosted as software as service platform. In this example, the shopping mobile app has to query against three separate systems and process the information retrieved from these systems.

Mobile app has to manage the data from various sources in its local database. We have given the popular mobile databases below –

- SQLite is one of the most popular mobile databases as it can efficiently store and process different formats of data. SQLite can run in the mobile devices as it uses minimal resources.

- AWS DynamoDB is one of the most popular NoSQL databases that can efficiently store the key-value pair data. Mobile apps use AWS DynamoDB to store the session data, shopping cart data and other key-value data pair.

- MongoDB is a popular opensource database for storing and efficiently managing the documents.

- Redis is a popular caching platform that can manage the frequently used data for use cases such as leaderboards, gaming applications.

- Neo4J is a popular graph database that can efficiently query the relationship between data.

12.2.1 Challenges in Mobile Data Management

The data requirements for Mobile apps are unique as they need to manage the large data volume with low latency and over unpredictable networks. Given below are the main challenges faced by the mobile databases –

Data Synchronization

The data has to be stored be stored in the local database as well on the remote database. We need to design the efficient data synchronization process to synchronize the local data with the remote database on the cloud.

Transaction Management

As the mobile apps work with distributed databases, maintaining the data integrity, ACID (atomicity, consistency, integrity and durability), strict consistency and the correlation of data across all the databases becomes a challenge.

Data processing

The mobile apps need to identify what data that needs to be processed on the client side and what data has to be processed on the server side. The data that needs heavy duty processing has to be done at the remote server end to ensure high performance.

Network Connectivity

Due to the dynamic nature of the mobile network, the mobile apps need to handle the data management in unpredictable network conditions. One of the popular approaches is to use offline-first approach wherein the data is stored locally during low network scenarios and it will be synchronized with the remote database when the network stabilizes.

Data Security

The data at rest and data in transit has to be secured through encryption, transport level security and other mechanisms.

Managing Location Dependency

Mobile apps need to handle the queries that are location dependent and need to manage other dependencies.

Resource management

As the mobile device has limited compute, storage and battery capacity, the mobile app has to manage the data within these constraints.

12.2.2 Handling Mobility Issues

Mobile devices are mostly on the move which brings in its own set of challenges and issues. When the mobile devices are on the move the strength of the signal may vary and sometimes the network may not be available. Another challenge is that the mobile battery

may be low and hence the background job and the mobile app should work in low power mode. Few of the mobile apps (such as restaurant finder, hospitals near me) need to be location aware and hence the query processing and data processing has to be location aware.

Mobility also impacts the power consumption of the mobile device. The mobile battery consumption varies based on the signal strength which also has to be factored in.

Location-aware computing during mobility

Given below are some of the main location aware computing that need to be handled as part of the mobility –

- Change of the cell tower due to change in location.
- Change of signal strength and hence change in battery consumption.
- Change in the wireless carrier during change of region (such as during international travel).
- Change of communication protocol (such as 5G to 4G)
- Change of business application (such as change from email to online meeting)
- Change in the service endpoint (such as corporate data center to cloud platform)
- Change of protocol (such as HTTP to UDP)
- Change of network (such as GSM to CDMA)
- Change in local security restrictions (such as restrictions to pre-paid plan in a given region)
- Change in time zone and its impact on time-based apps (such as calendar)
- Change in cost due to change of network.

Challenges and issues during mobility

Given below are the main issues and challenges due to mobility –

- Challenges in varying bandwidth and unpredictable network and the impact of network-intensive apps (such as maps, car rental apps)
- Varying power consumption due to the signal strength impacts the background apps and the resource intensive apps
- Handling transaction and the related data across various service endpoints and across heterogenous databases pose challenges.
- Handling the data backup jobs (such as photo sync up) during change in location.
- On-going call or video conference might get impacted due to change in the signal strength.
- Data synchronization between local database and remote database need to be handled when the network changes.

12.2.3 Handling Wireless Communication

Mobile device communicates with the nearest node of the cell for data communication. Based on the device location, the network may be partially or fully unavailable (such as at remote areas or in escalator). Additionally the available bandwidth is unpredictable which is based on the location and the amount of traffic at the given location.

Given below are the main factors of wireless communication that impacts mobility –

- The network bandwidth and the signal strength based on the location.
- Availability of network connectivity based on the location.
- Changing network topology (such as 3G to Wi-Fi)
- Limited battery power and compute and storage on the local mobile device.

12.2.4 Handling Mobile Portability

As mobile devices are resource constrained, the mobile devices need to manage the large amount of data generated by the mobile apps that require large storage and heavy-duty data processing.

Data portability involves replicating or moving the data across different servers, environments and across different operating systems.

Given below are the core best practices for handling mobile portability –

- Store the frequently used data in local data store (such as in SQLIte database) and synchronize the data from local data store to cloud database on frequent basis.
- Encrypt the data during transit to ensure data security.
- Backup the local data to remote servers on regular basis (such as for photos, videos and media files)
- Centrally store the core data (such as contact list, browser bookmarks, chat conversations) for security reasons.
- Use an open-standard data format to provide flexible and extensible data replication (such as using JSON or XML file formats).
- Cache the frequently used data for optimal performance.
- Adopt offline-first approach to manage data locally when there are no networks.

☞ Check Your Progress 1

1. _____ database is used for managing documents.
2. _____ database is used for efficiently querying the relationships.
3. _____ is a popular caching framework that can be used for managing the frequently used values.
4. Local database and remote database is kept up to date through _____.

12.3 DATA REPLICATION SCHEMES

Mobile device stores the data of many mobile apps. A camera app stores the captured photos and videos whereas a messaging app stores the shared files in the mobile device. As the size of the stored files increase, we need to manage the risk of data loss, security and durability.

Data replication is a mechanism wherein the data on the mobile device is replicated to another computer or device or remote cloud server. If the copied data changes in the target (such as remote cloud server), the updated data is replicated back to the mobile device. In summary the changed data is synchronized across all the devices.

Given below are the main advantages of data replication -

- Data replication ensure the high durability of data
- Data replication improves the reliability and availability of the data.
- Data replication optimizes the latency (as data is stored nearer to the location of access) thereby improving the data access performance.
- Data replication allows the queries to use the data from a single location thereby reducing the query complexity.

12.3.1 Data Replication Methods

There are mainly three kinds of data replication methods. In the one-to-one data replication method as depicted in Figure 2, the user uploads the data to a server or PC and it gets replicated to the mobile device. If the data changes either in the server or in the mobile device, the updated data is synchronized to the other system. An example of one-to-one data replication is the user specific data backup (such as files, media files) between user's PC and user's mobile device.

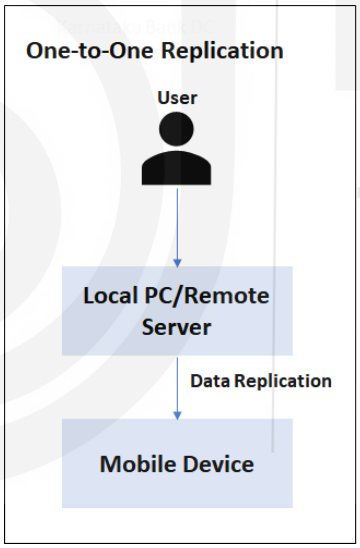


Figure 2 One-to-one replication

In a one-to-many replication scheme, the user copies the data to the centralized server which then replicates the data to various mobile devices as depicted in Figure 3. An example of one-to-many data replication is the security policy replication between an organizational server and all the manged mobile devices belonging to its employees.

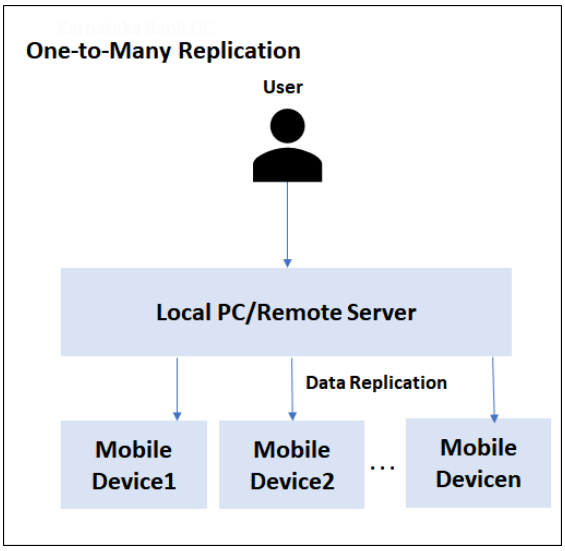
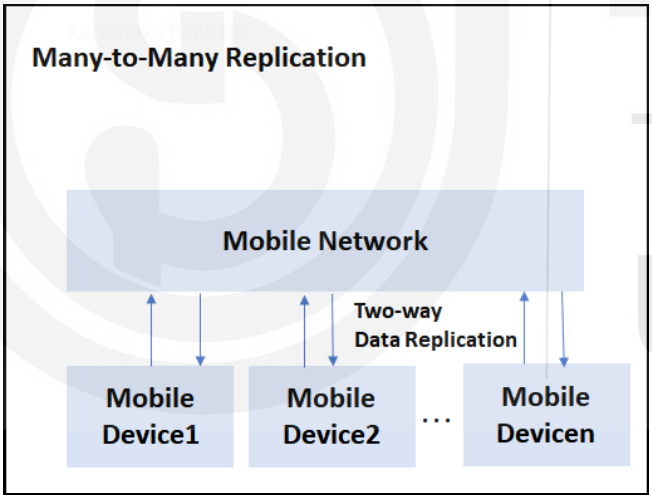


Figure 3 One-to-many replication

In many to many data replication, multiple mobile devices perform bi-directional replicational of the data through the mobile network as depicted in Figure 4. Multi-player game is an example of many-to-many data replication wherein the game data is continuously replicated across all the mobile devices of the participating players.



12.3.1 Considerations for Data Replication

As data replication involves copy data across various devices, we need to factor in various design considerations for data replication. We have given the key design considerations for data replication below –

- Data synchronization task - We need to design the data synchronization job that handles the incremental data replication across devices. The data synchronizer task has to synchronize the data at specified time intervals.

- Data merging and conflict resolution – During many to many data synchronization as the data from multiple device needs to be synchronized, the synchronizer has to handle the conflict resolution (when the same object has been updated simultaneously by two different devices) and data merging (merging the changes).

- Data security – The data replication job should also ensure that data is securely copied to the target locations.

- Handling data schema changes – Different domains have different data schemas and as such the data replication job has to ensure that a common schema based on open standards (such as JSON or XML) is used for data replication.

- Handling data conversion – Due to the heterogenous nature of the devices, the data may need to be converted during the data replication process.

12.3.2 Data Replication Types

There are broadly two main types of replication – full replication and partial replication.

In full replication the entire data is replicated across devices. For instance, the mobile device copies all the images from the device to the cloud drive. In the partial replication, only the limited set of data to the target device. For instance, the mobile device replicates only the data updated on the day to the central server on daily basis.

Pull and push synchronization

In traditional client-server kind of scenario, the server pushes the data on a frequent basis. The client device caches the pushed data in its local data store and uses the data for its mobile apps. The client mobile device regularly pulls the updated data from the server. An example for this model is a gaming mobile app wherein the game mobile app running on the local device gets the complete set of game rules during the one-time setup. Post the mobile game app installation, the app regularly pulls the updated game rules from the centralized rules database on daily basis. This method is also known as "one-to-many" communication wherein a single server pushes the data and many clients pull the data.

The second model of synchronization is that a single device will pull and push the information as in the case of peer-to-peer communication. An example for this model is a peer-to-peer sharing mobile app that shares the data and files to another mobile device.

Synchronous and Asynchronous replication

In synchronous replication, the data is replicated continuously in real time synchronously. Synchronous replication is used in strongly consistent use cases. For instance, a stock trading application replicates the transaction data in real time.

Asynchronous replication replicates the data asynchronously in batch mode. This improves the performance and optimizes the

12.4 ADAPTIVE CLUSTERING

Adaptive clustering is a dynamic grouping of mobile devices to improve performance and optimize the energy consumption. The grouping of mobile devices happen based on their location proximity and communication protocols.

In order to conserve the consumed energy, the mobile devices communicate with its nearest neighbors instead of transmitting the signal to all the mobile devices. By localizing the communication, we can optimize the latency and conserve the energy.

12.4.1 Adaptive Clustering Process

In this section we have explained the process of adaptive clustering

Cluster formation

Various factors such as the mobile device's signal strength, distance, communication protocols, network load are used along with clustering algorithms (such as distance based clustering, traffic load based clustering, mobility based clustering) to create the clusters.

Device communication

Post cluster creation, the mobile devices in a given cluster communicate directly. To communicate with other clusters the mobile devices use cluster heads that act as gateway to across the clusters.

Cluster reconfiguration

The cluster is re-adjusted dynamically based on the changing conditions. For instance, if the mobile device moves out of the location range, the mobile device is removed from the cluster and added to a new cluster to ensure optimal performance and optimal energy consumption.

We have depicted a sample adaptive clustering in Figure 4

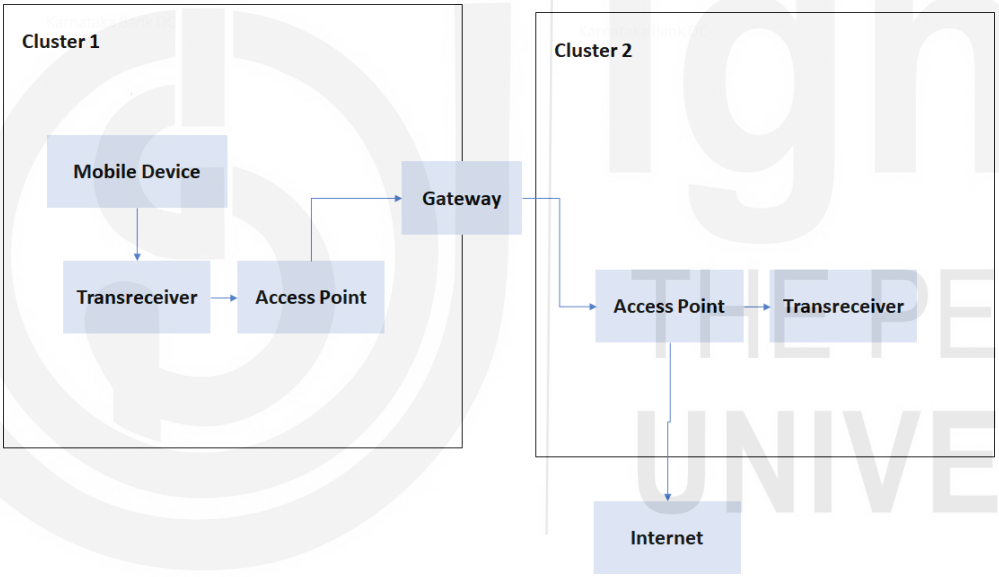


Figure 4 Sample Adaptive clustering

☞ Check Your Progress 2

1. In _____ replication method, the data from the server or PC and gets replicated to the mobile device.
2. In _____replication method, the data from a centralized server replicates the data to various mobile devices.
3. In _____ replication method bi-directional replication happens across various devices.
4. In _____replication, the data is replicated continuously in real time.
5. _____ clustering is a dynamic grouping of mobile devices to improve performance and optimize the energy consumption.

12.5 SUMMARY

In this chapter we discussed various concepts related to data handling schemes of mobile devices. Mobile devices use data distributed across various datastores. Mobile app uses various database such as SQLite (for managing data locally), MongoDB (for document management), Redis (for caching), DynamoDB (as NoSQL database for key-value pair), Neo4J (for graph use cases). The main challenges in mobile data management are Data synchronization , Transaction management ,Data processing, Network connectivity, Data security, Managing location dependency and Resource management. Varying bandwidth, varying power consumption, handling transactions, handling data backup jobs are the key Challenges and issues during mobility. The core best practices for handling mobile portability are local data caching, data encryption, data backup, open standards, caching. The three kinds of data replication methods are one-one, one-to-many and many-to-many. Adaptive clustering is a dynamic grouping of mobile devices to improve performance and optimize the energy consumption.

12.6 SOLUTIONS/ANSWERS

Check Your Progress 1

1. mongodb.
2. Neo4j.
3. Redis .
4. Data synchronization

Check Your Progress 2

1. One-to-one.
2. One-to-many
3. Many-to-many
4. synchronous
5. adaptive

12.7 FURTHER READINGS

References

https://en.wikipedia.org/wiki/Network_virtualization

https://en.wikipedia.org/wiki/Cloud_computing

UNIT 13 SMART CLIENT AND ENTERPRISE SERVER BASED ARCHITECTURE

Structure

13.0 INTRODUCTION

13.1 OBJECTIVES

After going through this unit, you should be able to

- understand key concepts of mobile data management,
- understand data replication schemes,
- understand key concepts of adaptive clustering
- Understand the mobile device support infrastructure.

13.2 INTRODUCTION TO SMART CLIENT ARCHITECTURE

In a typical n-tier application a web application client collects the data from the end user. For instance, an end user fills up the registration form and submits the form. The web client then sends the data in the prescribed format (such as JSON) to the server.

At the server end, we have the server components such as load balancer and web servers. The web server runs a microservice that validates the data and stores the data in the database. During the registration process the system also generates a unique customer registration id.

The Smart client sends the request to the server which aggregates the response from various data stores. Optionally we use gateways at the sender end and at the

receiver end which is responsible for data transmission, protocol conversion and data transformation.

13.2.1 Smart Client Architecture

In a typical 3-tier enterprise application, we have separate software components/modules to mange the presentation (such as React, Angular, JSP, PHP, .Net), business logic (such as .Net, Spring Boot, NodeJS and others) and database interactions. Let us look at how thick client, thin client and smart client applications mange the modules.

There are multiple ways to develop client software for mobile platforms. In this section we discuss the three main approaches.

Thick Client Architecture

The thick client architecture encompasses all the tier components in a single structure. We have depicted the thick client in Figure 1. Given below are the main tenets of thick client architecture –

- The solution components of all tiers are present as part of single thick client
- Thick client does not communicate online to get the data required for the application to function.
- The thick client components are tightly coupled.

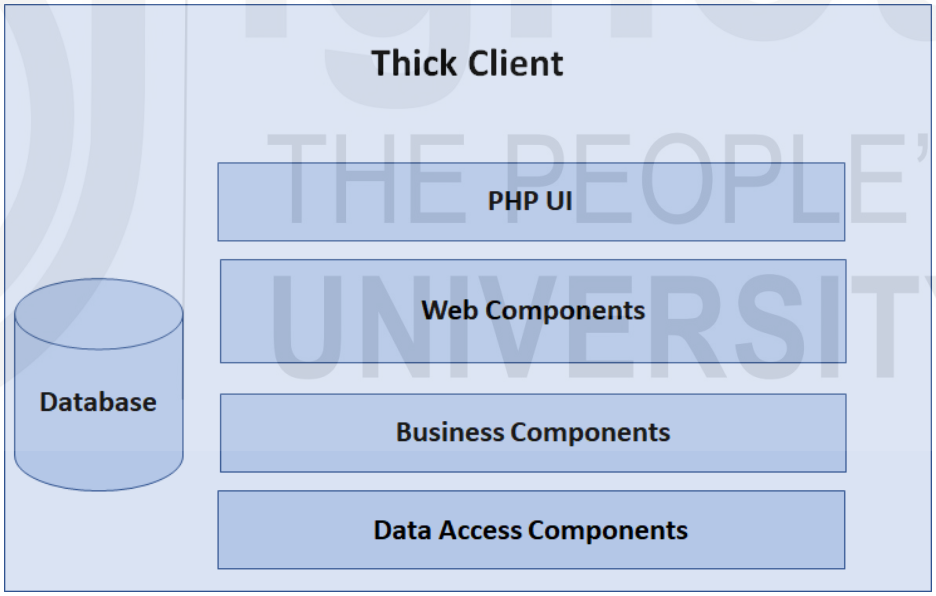


Figure 1 Thick Client Architecture

An example for a thick client is a mobile gaming app that has the components from all the tiers in a single app. The gaming app does not use online services.

Thin Client Architecture

Thin client architecture involves minimal components on the presentation tier as depicted in Figure 2. Given below are the key tenets of thin client architecture –

- The presentation tier has only the components required to render the user interface. For instance, web pages, images, stylesheets, JavaScript libraries.

- Thin client invokes backend services for all the required information.
- The data required for the presentation is retrieved through the backend service call.

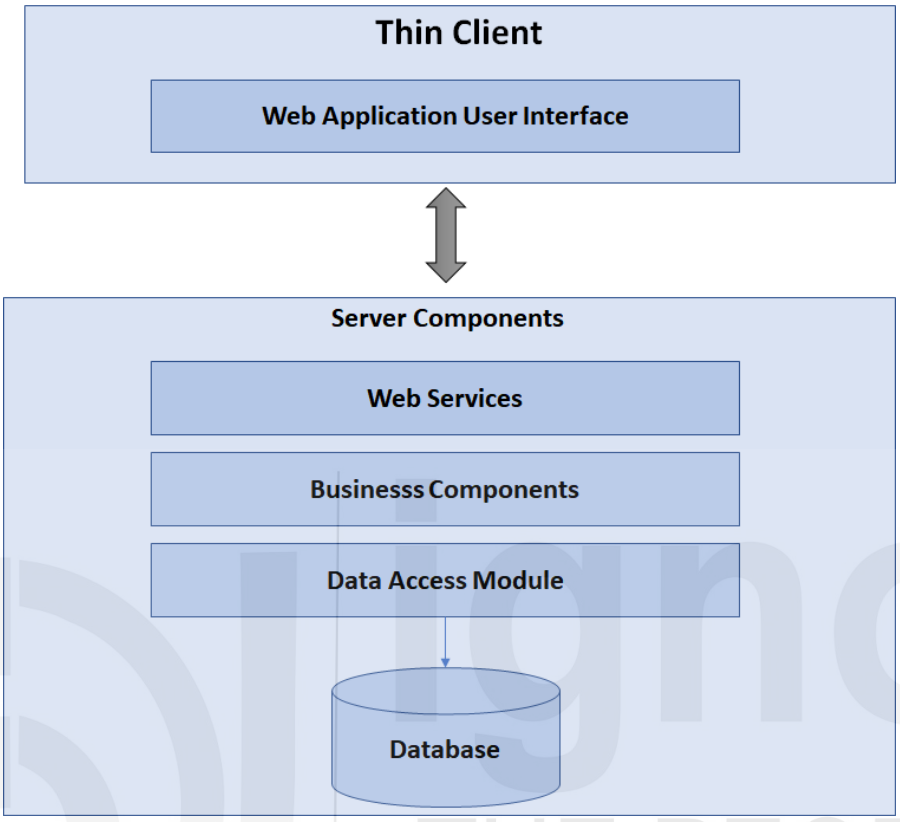


Figure 2 Thin Client Architecture

An example of thin client architecture is the web platform that invokes backend services for all the required data.

Smart Client Architecture

Smart client applications are thin clients that use local database storage for managing the data. Smart clients enable us to implement offline-first approach wherein the applications work in limited network conditions and during no network conditions by using the local storage. Smart clients synchronize the data to the servers when the network is available. Smart client applications are also called rich internet applications as they provide engaging user experience. For instance, a gaming mobile app that ranks the players based on their game score, stores the game score in local database when the network is not available and later synchronizes to the server when the network becomes available.

We have given the smart client architecture in Figure 3. Given below are the key tenets of the smart client architecture –

- The smart client runs on the mobile device and connects to Internet through mobile carrier.
- The data is retrieved from the database server and synchronization server synchronizes the data across database instances.
- The performance of the smart client is optimized as it uses local data cache.

The main challenge in the smart client is the heterogeneity of the mobile platforms. Normally popular mobile smart clients are developed in both android and Apple iOS platforms. Alternatively, we can use hybrid mobile platforms such as Kotlin.

Given below are the main advantages of the smart client architecture -

- It provides rich user interface
- Provides effective user experience
- Leverages the native mobile features such as camera, sensors and such
- Ensure high security
- Can work in low bandwidth conditions
- Provides the rich user experience of thick client and the light weight design of the thin client application.

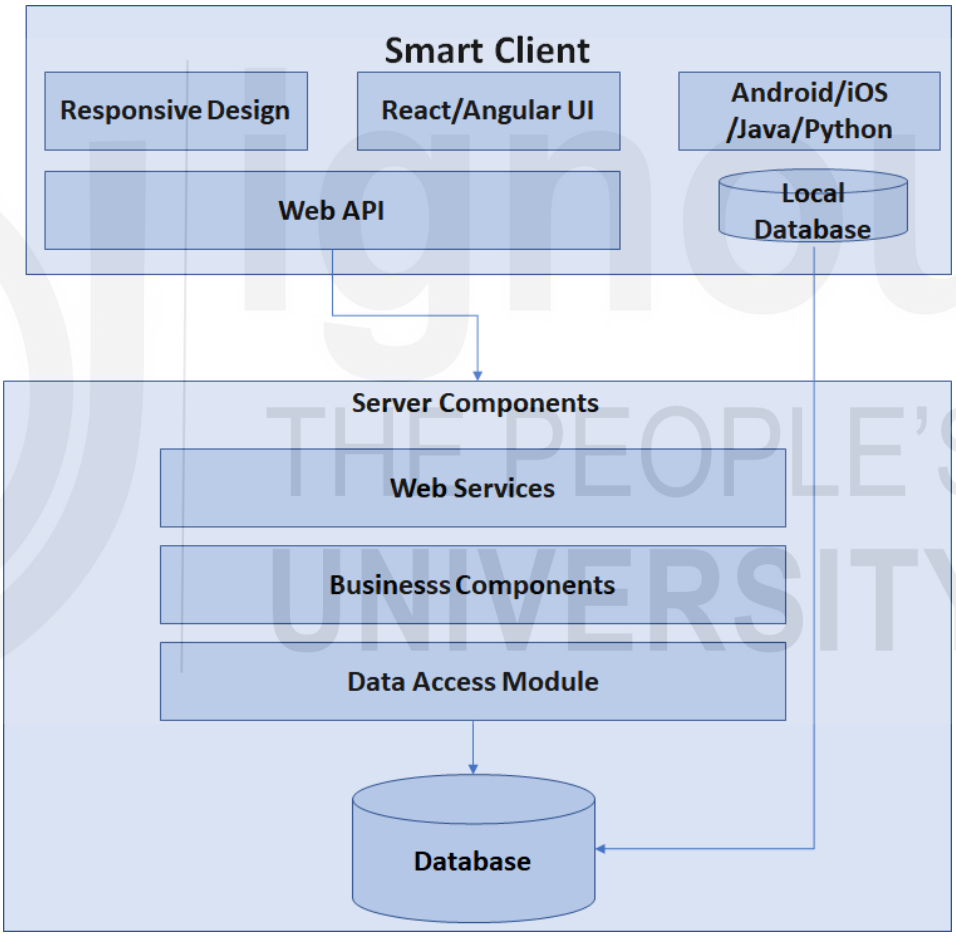


Figure 3 Smart Client Architecture

13.2.2 Differences between the Architectures

Table 1 provides the key differences between thick client, thin client and smart client.

Table 1 Thick Client vs Thin Client vs Smart Client

	Thick Client	**Thin Client**	**Smart client**
Data sync	No data sync	No data sync	Frequent data sync
Connectivity	No connectivity	Frequent connectivity	Synchronize local data with remote DB

Advantages	Rich user experience	Light weight design	Rich UI and dynamic data
Disadvantages	Large size without any dynamic data	Frequent server calls & low performance	Not applicable
Size	Large (in MBs)	Small (in KBs)	Small (in KBs)
Example	Windows applications	PHP, JSP, .Net based applications	React/Angular/Vue based applications with local data store

13.2.3 User Interface of Smart Client

The user interface of smart clients should engage the end user. We have given the key design goals for the smart client user interface –

- The user interface should be simple and consistent.
- The user interface should provide intuitive information architecture.
- The user interface should be accessible to all users.
- The user interface should be personalized based on user goals, needs and wants.
- Users should be able to quickly find the relevant information.

The user interface for smart clients use various pattern such as atomic design pattern, client-side UI composition pattern and such. In these patterns we create the larger (or higher order) user elements using smaller and reusable library of user elements. For instance, the mobile screen consists of form and menu UI elements. The form UI element is further composed of text items, drop-down list, radio button, submit button, checkbox and other reusable library of UI elements.

The advantage of using atomic design pattern and client side UI composition pattern are as follows

- We can implement a consistent user experience across the entire application
- We can reuse the library of UI components
- We can build standards based, consistent user experience.

13.3 DATA SYNCHRONIZATION FORMATS

Mobile devices often synchronize the local data with remote servers to prevent the data loss. We have specified the main advantages of data synchronization below –

- Ensure high availability of data across different devices.
- Backup the data in remote device
- Restore the back during data loss

The data format in the source device (such as mobile device) and the target device (such as remote server or PC) might be different. In such case we need to convert the source file format into the target file format.

The data synchronization can be scheduled or automated or can be user based. We can schedule the data synchronization from the mobile device to the remote server based on

the importance of the file. We can also specify the auto-synchronization policy. For instance, when the mobile device connects to the PC through USB, the data is automatically synchronized. The mobile user can also choose to selectively synchronize the data of interest. The user can look at the update report that details the updated/deleted/added data on the source and target device and then chose to synchronize the data. The user can also use conflict resolution policies to update or override the data if the data is updated both on source and the target.

In this section we shall look at common data synchronization formats.

13.3.1 Open Standard Formats

Modern mobile devices support the open standards such as XML, JSON, VCF based data synchronization. Initially we perform the full backup and then we synchronize the incremental changes on daily basis. For instance, the contact list on the mobile device can be synchronized and shared using virtual card format (VCF).

13.3.2 Flat File Format

Flat files such as PDFs, Microsoft word document, Image files (PNG, JPG) are synchronized from the source device to the target device.

While synchronizing the flat files, the entire file is synchronized as many of these file formats are in proprietary binary format. The modified timestamp is used to identify the latest copy of the file and it will be synchronized with the target device.

13.3.3 Database Format

Many mobile devices store the information in its local database that consist of data records and indexed by the key columns. For instance a user profile information table has indexes on user name and phone number or email address as these are the commonly used fields. The indexes are used to speed up the database queries.

When we synchronize the data to the database record we can update individual table rows which are updated. For instance, we can update only the phone number of the user when the user changes the mobile number.

13.3.4 Device Specific Storage

Each of the mobile device has its own format for specific functions. Given below are few examples

- Android platform supports AAC LC, MIDI, MP3 for audio whereas Apple devices support AAC (Apple audio communication).
- Android uses vCalendar file format for calendar. The calendar can optionally contain vtodo, vjournal components.

☞ Check Your Progress 1

1. The architecture that includes all solution components in a single tier is called _____
2. The key difference between thin client and smart client is _____
3. The main disadvantage of thin client is _____
4. The main data synchronization formats are _____

13.4 DATA SYNCHRONIZATION AT CLIENTS AND SERVERS

The mobile device gets the updated data such as messages, emails, app data from the server. The data is synchronized between the server and the mobile client securely and regularly.

In this section we discuss various topics related to synchronization such as synchronization types, usage models and others.

13.4.1 Synchronization Types

The mobile client and the remote server use various synchronization methods to update the data. Let us look at the different types of synchronization –

Two-way synchronization

In a two-way synchronization, the data is synchronized bi-directionally between mobile client and the server. Whenever the mobile client connects to the server the updated data is synchronized with the server.

For instance, when the user adds a new contact in the mobile device, the updated contact details are synchronized with the remote server when the mobile device connects to the server. Similarly if the remote server has an updated patch file, it synchronizes with the mobile device.

Synchronization on server alert

In this scenario, the data is synchronized from the remote server to the mobile client. Whenever the server gets a new data that is required for the mobile client, it alerts the mobile device. The mobile device then pulls the updated data from the remote server.

For instance, when a new message arrives for the mobile device at the server, the server alerts the mobile client which then pulls the updated message from the server.

Server initiated synchronization

The server initiates the synchronization when the data is updated on the server end. The updated data is identified based on its last modified timestamp. During the synchronization, the updated data is synchronized to the mobile client.

For instance, the server initiates the synchronization when a new email arrives for the mobile device. Upon receiving the email message, the server pushes the email to the mobile client.

Synchronization upon client request

The mobile client requests the server to refresh its data. For instance, the mobile client requests the server to refresh its locally stored spam list or any of the mobile app configuration file. Upon this request, the remote server synchronizes the latest data for the spam list and pushes the latest configuration file.

Client initiated synchronization

In this scenario, the client pushes the updated data to the remote server. For instance, the application configuration, user preference data, analytics data, click-stream data is pushed from mobile client to server when the data is updated.

A variant of this model is that client can back up the local data on the remote server. Whenever the data is updated, the mobile device backs up the data remotely.

Generally during the synchronization, only the updated data is synchronized from the source to the target. In a bi-directional synchronization, the synchronization system compares the data on both client and the server and uses conflict resolution rules to update the data. If the data is updated at both client and the server, the data is either merged or overwritten based on the preference.

13.4.2 Synchronization Usage Models

A typical mobile computing system consists of various components such as the following:

- Mobile client that interacts with the mobile computing ecosystem by invoking APIs
- Mobile carrier that provides necessary network coverage for data transmission.
- A local PC or remote sever that connects to the mobile client for data backup.
- A resource such as Bluetooth speaker or a smart TV to which the mobile client connects.

The mobile client employs multiple usage models to synchronize the data with the mobile computing ecosystem. We have detailed the main usage models in this section.

API based synchronization

In this method of synchronization, the mobile client API synchronizes the data with a remote server or a resource through API running on the target device. We have depicted the API based synchronization in Figure 4.

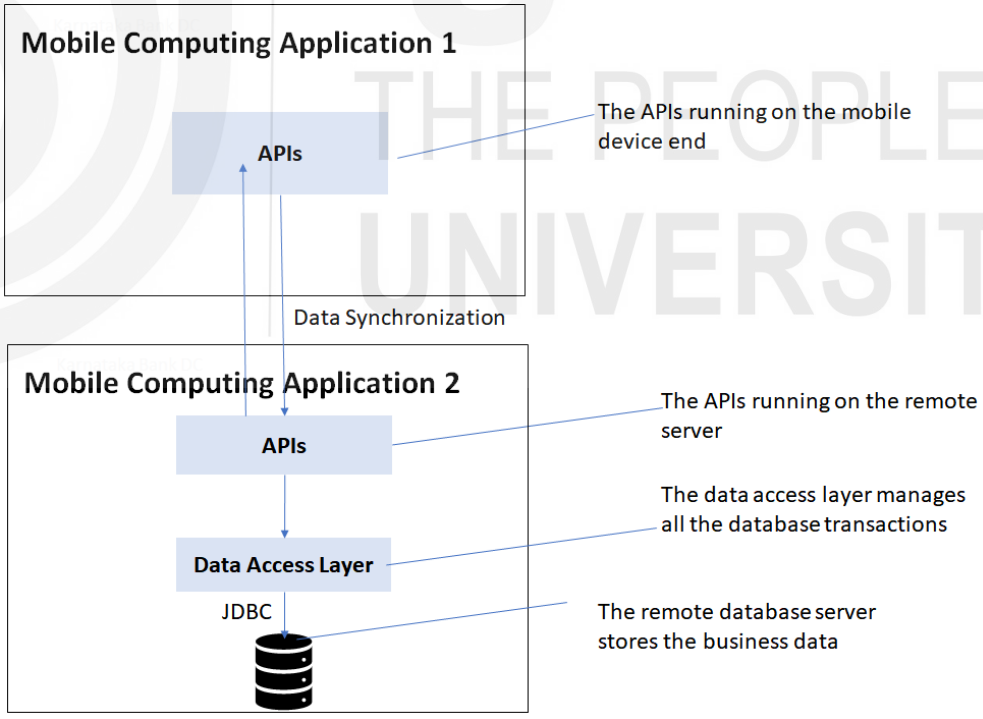


Figure 4 API based synchronization

For instance, a user profile management API running on the mobile device synchronizes the user profile updates to the remote server.

Synchronization to nearby PC

In this method the mobile device synchronizes the data with the nearby device such as personal computer (PC) or a Bluetooth device. We have depicted the synchronization in Figure 5.

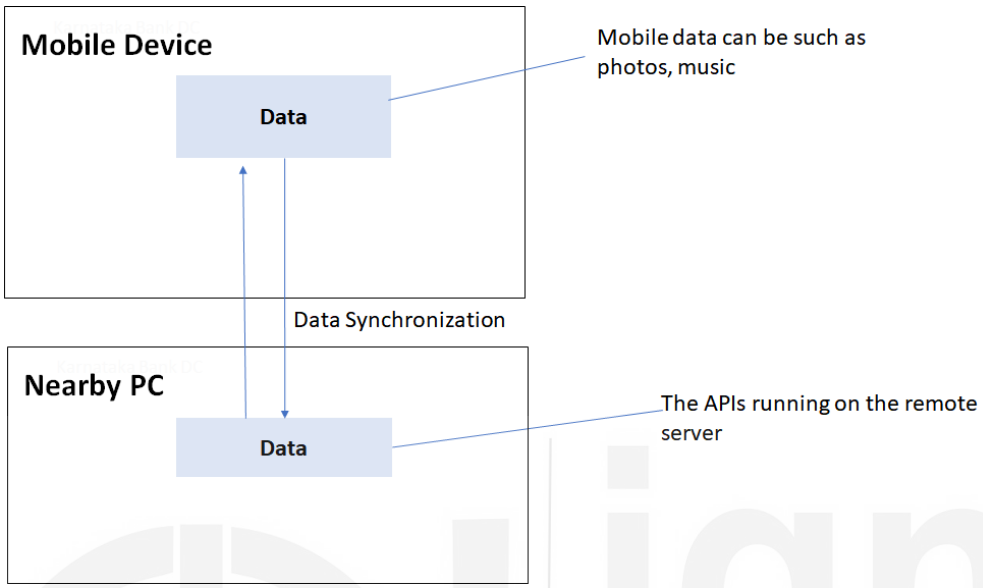


Figure 5 Synchronization between mobile device and nearby PC

For instance, the mobile device client synchronizes the files or music videos to the nearby PC through USB or Bluetooth.

Synchronization to remote server

In this synchronization method, the mobile device connects to the remote server through WIFI or wired Internet and synchronizes the data. We have depicted the remote server synchronization in Figure 6. A variant of this approach is that mobile device uses an intermediate system (such as local PC) to synchronize the data with the remote server.

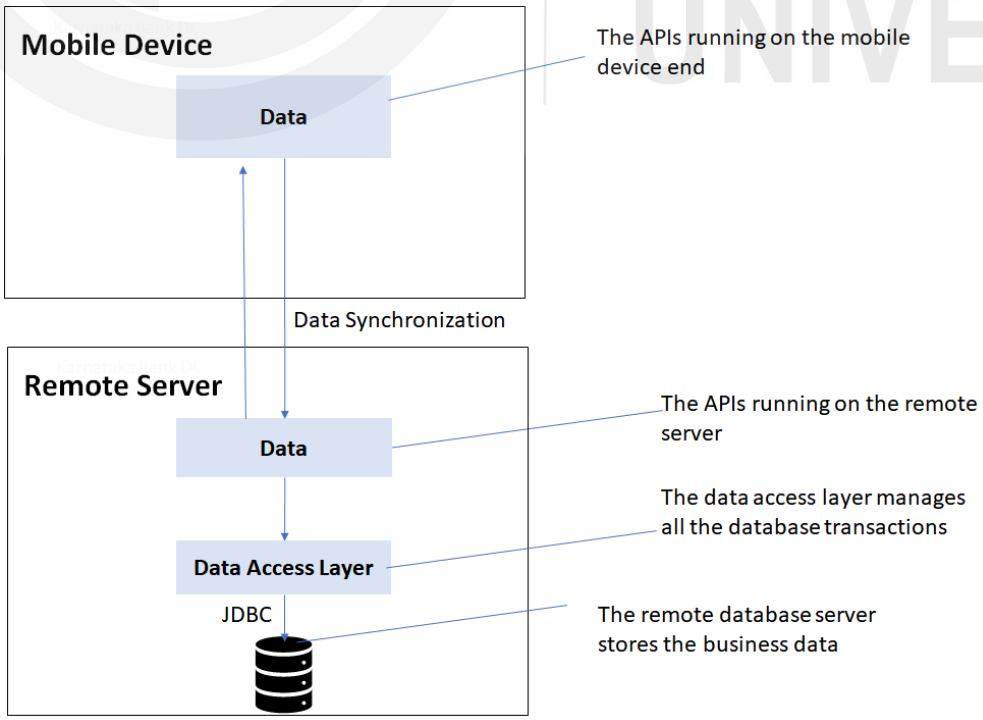


Figure 6 Synchronization with remote server

For instance, the mobile device backups the messages to the remote cloud server.

13.5 MOBILE DEVICES SUPPORT INFRASTRUCTURE AND MANAGEMENT

An enterprise needs a centralized device management platform to manage the heterogenous mobile devices. Given below are the main features of a device management platform –

- Bootstrapping the device with initial configuration
- Monitoring the configuration changes
- Handling the device maintenance
- Managing the device location and device handover

In this section we discuss the mobile device support infrastructure

13.5.1 Mobile Device Support Infrastructure

The mobile service provider should manage the wireless infrastructure (such as network coverage, mobile SIM registration, call management and others). If the mobile apps need additional security features such as multi-factor authentication (MFA), then the device support infrastructure should manage those requirements as well.

The mobile device also should work transperently from the device management team. When the mobile device starts up, it should register itself to the network. The mobile device should perform activities such as setting up the communication, initiating the call, terminating the call, closing the communication and such. We have depicted the mobile support infrastructure in Figure 7.

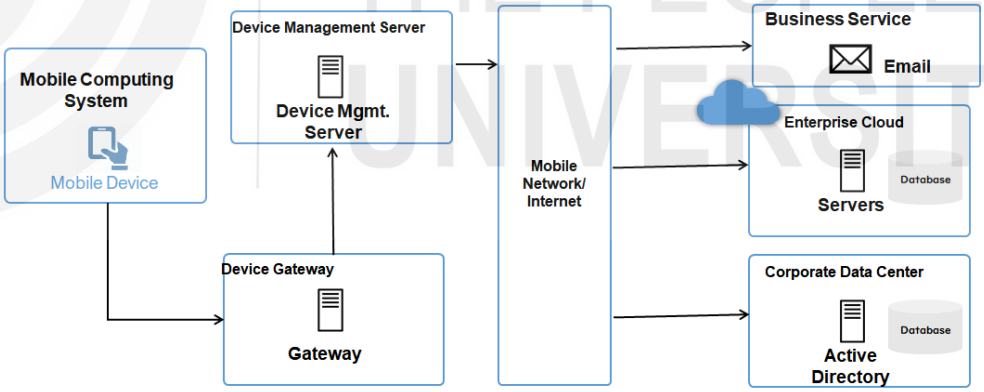


Figure 7 Mobile Device Support Infrastructure

The main steps of the mobile support infrastructure is as follows –

1. The mobile computing system (such as mobile devices) connect to the device gateway. The device gateway acts as an intermediator between the mobile client and the device management server.

2. The device management server assigns a unique id to all the registered mobile devices. The mobile device details are tracked using the unique id. If the mobile device moves to a different location, the id is changed accordingly.

3. The device management server connects to the Internet.

4. Through the Internet the mobile device can connect to enterprise data center (which is hosting the enterprise database and services), enterprise cloud platform (which is hosting the cloud services and servers) and business services (such as email, ERP and such).

☞ **Check Your Progress 2**

1. Bi-directional synchronization happens in _____
2. The main synchronization usage models are _____
3. Server pushing the new email to mobile client is an example of _____
4. Mobile client requesting to update its configuration file is an example of _____
5. _____ acts as an intermediator between the mobile client and the device management server.

13.6 SUMMARY

In this chapter we discussed various kinds of mobile architecture. There are mainly three types of mobile related architectures- Thick client architecture, think client architecture and smart client architecture. The thick client architecture encompasses all the tier components in a single structure. Thick client does not do server calls. Thin client architecture involves minimal components on the presentation tier and invokes backend services for the data. Smart client applications are thin clients that use local database storage for managing the data. Smart clients provide rich user interface, effective user experience and leverages native mobile features. The main data synchronization formats are Open Standard Formats , Flat File format, Database format and Device specific storage. The main synchronization types are Two-way synchronization (wherein bi-directional synchronization happens between mobile client and the server), Synchronization on server alert (wherein the server alerts client for synchronization), Server initiated synchronization (wherein server initiates the synchronization when the data is updated on the server end), Synchronization upon client request (wherein the client requests the server to refresh its data) and Client initiated synchronization (wherein the client synchronizes the data to the server). The main synchronization usage models are API based synchronization, Synchronization to nearby PC and Synchronization to remote server. The mobile support infrastructure mainly consist of the device gateway, device management server and the Internet that connects to the enterprise servers.

13.7 SOLUTIONS/ANSWERS

Check Your Progress 1

1. Thick client.
2. Local storage
3. frequent server calls
4. Open standards, device specific storage, flat file format and database format.

Check Your Progress 2

1. Two-way synchronization.
2. API based synchronization, Synchronization to nearby PC, Synchronization to remote server,

3. Server initiated synchronization
4. Synchronization upon client request
5. Device gateway

13.8 FURTHER READINGS

References

https://en.wikipedia.org/wiki/Network_virtualization

https://en.wikipedia.org/wiki/Cloud_computing

UNIT 14 MOBILE INTERNET APPLICATIONS

14.0 INTRODUCTION

Markup language will generate page layout , presentation components and enable us to interact with the server. Mobile app is a software that runs on the mobile device that provides the user interface for interaction.

For web pages the most popular markup language is HTML (hypertext markup language). HTML defines the web page components so that the browsers can render the web page as per the specification. HTML also posts the client requests to the server and gets them server response.

Mobile applications use XML for managing the data. Mobile devices use that networks like 3G 4G 5G and protocols like wireless application protocol (WAP) to connect to the internet. The connecting devices use xml-based wireless markup language (WML) for exchanging information.

14.0.1 Mobile Application development

Mobile application provides the mobile user with a graphical user interface and intuitive interfaces to get the required information. Modern mobile applications and use n tier architecture where the mobile app acts as a client and the server is deployed on a remote machine the server managers are huge database and provides API is to expose the data to the mobile client.

There are primarily two to main development platforms for mobile app iOS and Android. Android mobile apps can be developed in Java and the iOS mobile apps are developed in frameworks such as swift UI and UI kit.

Mobile app provides the below given functionality:
1. Creation of a graphical user interface
2. Allowing the end user to use the gestures, clicks to interact with application
3. Interface with remote service to get the data on demand.

How to develop the mobile app we need to follow the below given steps:

1. Select the mobile platform and the integrated development environment (IDE) to develop the mobile app in the selected language.
2. Develop the screen designs user interfaces libraries and integrations for the mobile app
3. Iteratively test the mobile app to ensure that the app conforms to the specifications
4. Package the mobile application for the platform
5. Host and distribute the application to the app Marketplace
6. Deploy the application to the end mobile device
7. Monitor the mobile performance and other related metrics

14.0.2 Components of Enterprise application

Let us look at the structure of the enterprise applications in detail in this section. We need to understand various layers of a typical enterprise application and the responsibility of each of those layers

Figure 1 provides the layer-wise components in a typical enterprise application. The channels provide the users access to various modes for interacting with the enterprise application. The user experience layer in the mobile app provides various capabilities for end users to interact. The API layer exposes the business capabilities to the presentation layer. The integration layer interacts with the backend system to get the enterprise data.

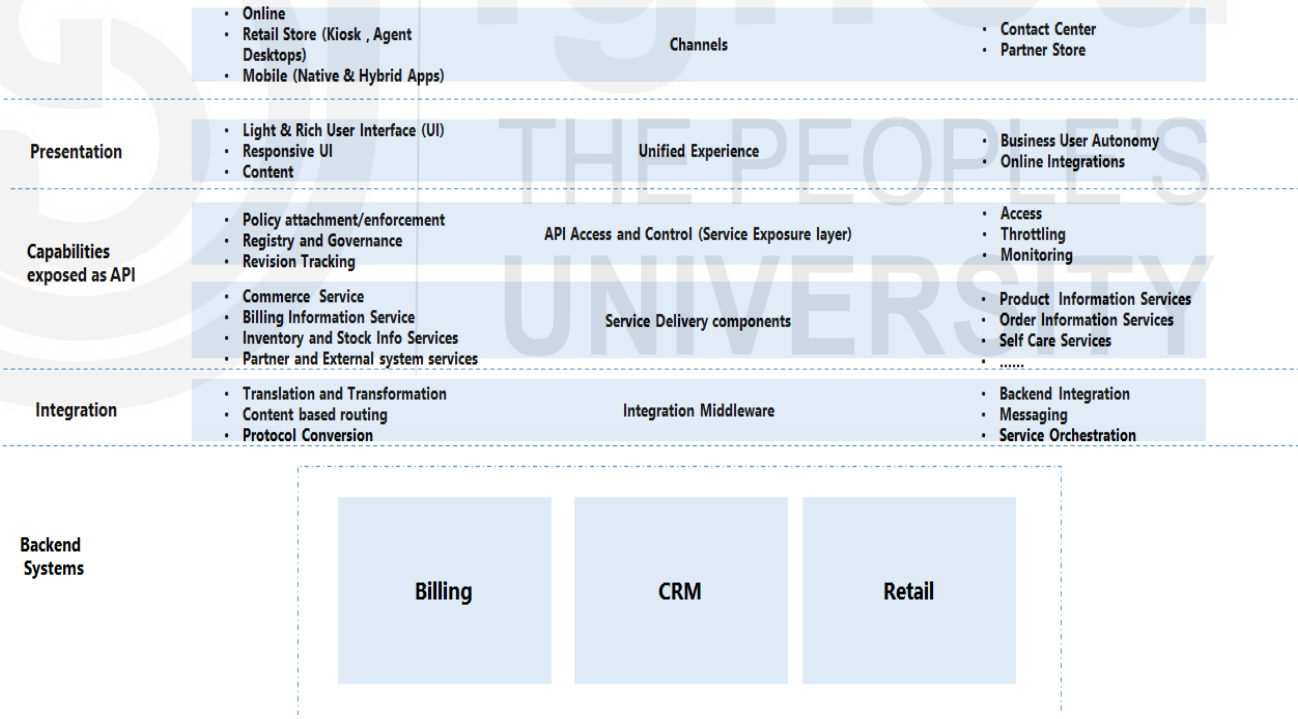


Figure 1 Layer wise Enterprise Application components

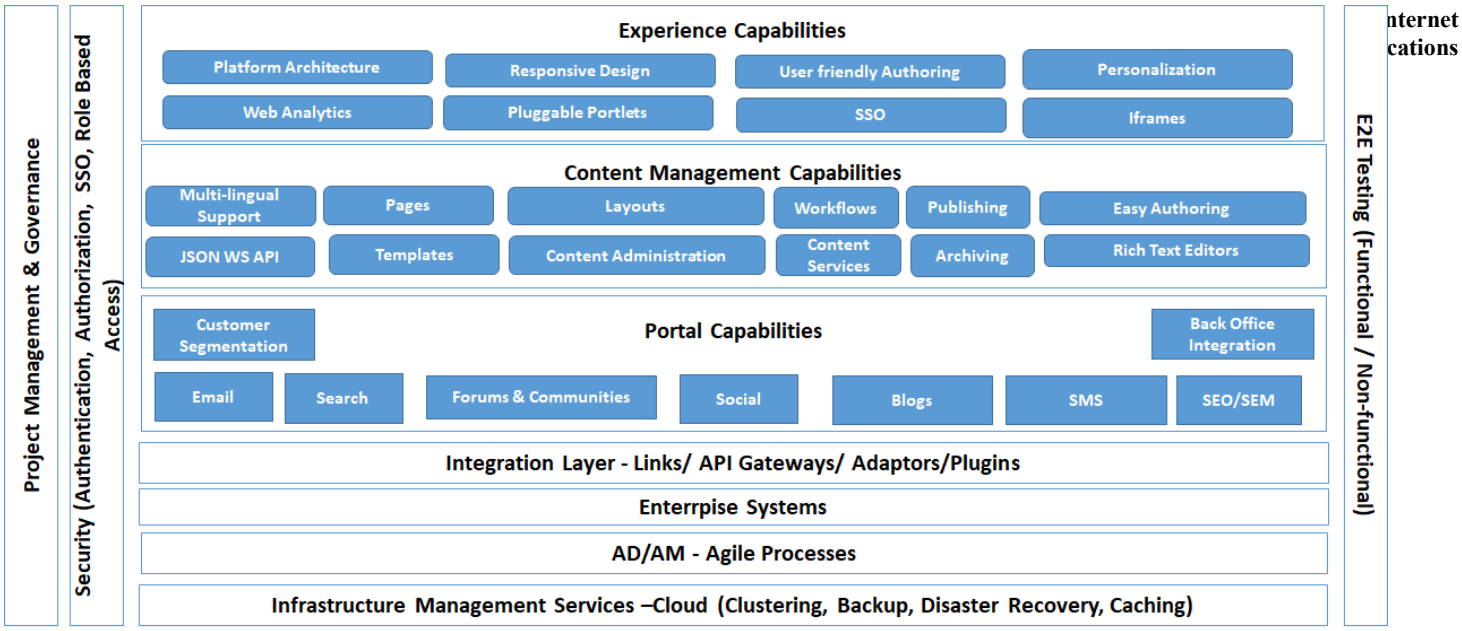


Figure 2 Content management application

In a content driven application the server layer mainly consists of content management features such as layouts, workflows, authoring etc. as depicted in Figure 2. Personalization, web analytics and responsive design are main features in the presentation layer.

The detailed components for each layer for an insurance application is depicted in Figure 3.

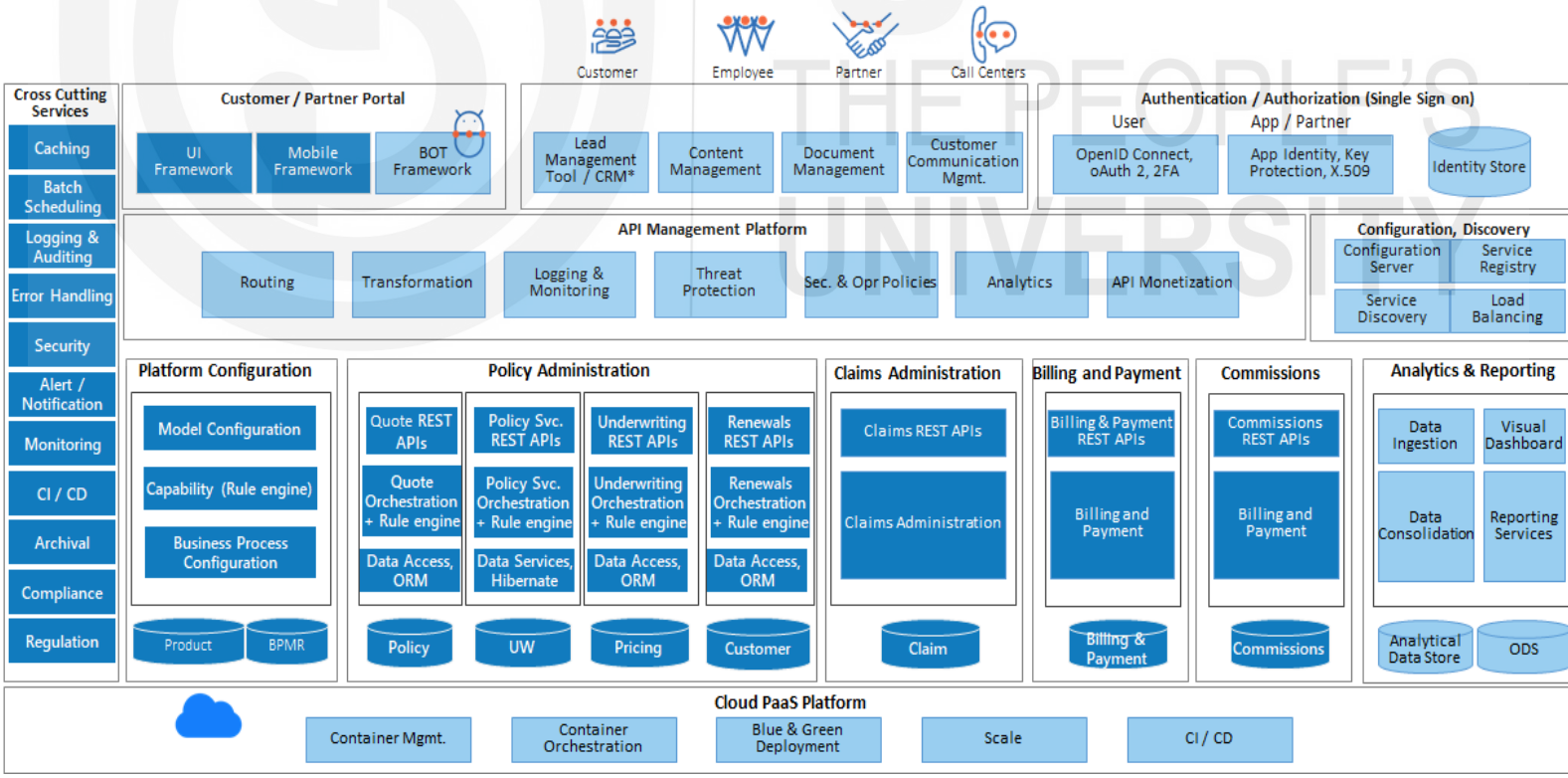


Figure 3 Layer wise components for Insurance application

The business components mainly consists of policy administration, claims management, billing and payment, commissions and analytic and reporting as depicted in Figure 3.

The main enterprise systems are depicted in Figure 4. In a typical enterprise application we have document management system, content management system, workflows, enterprise apps, collaboration apps and services. The middleware provides the services on top of the enterprise systems. The front end component such as login, dashboards, collaboration UI are part of the web page and the mobile app

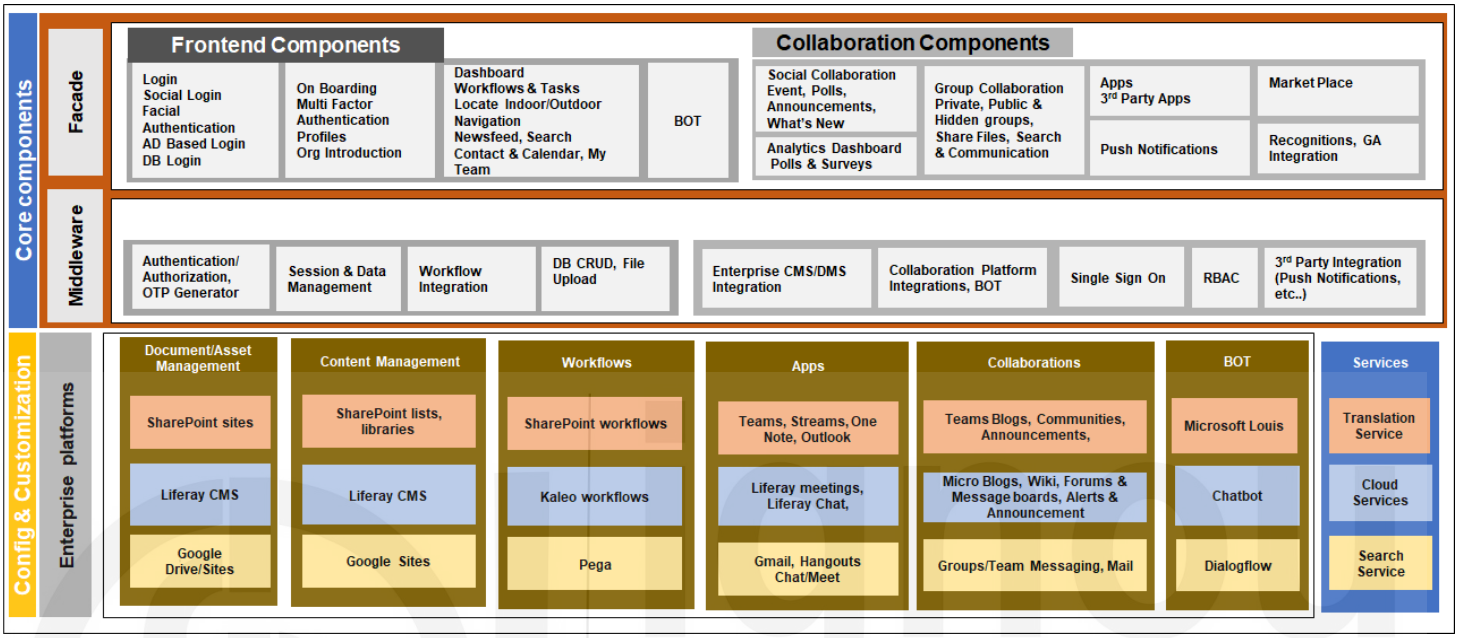


Figure 4 Enterprise Systems

14.1 OBJECTIVES

After going through this unit, you should be able to

- understand key concepts of XML,
- understand various types of device markups,
- understand the details of WML,
- understand HTML5 standard

14.2 INTRODUCTION TO XML

Extensible markup language (XML) is a declarative markup language uses standard set of tax and attributes for the presenting the data. The tag defines The high-level element entity and attributes define the properties of the entity. There are multiple XML based standards that's popular for data exchange and data transmission. XML is a platform and language independent structure format.

XML format is used in variety of scenarios. Firstly XML helps us to manage the data in structured way using well-defined tags and attributes. We can also define the information rules and constraints. XML is also used to share the data across

two systems using standard formats. Servers can push the data to the mobile clients using XML data format. We can also represent the object relationship and hierarchies in XML format. XML can be used as a database where we manage the information and XML can also be used to specify the commands, define the page layout, specify the constraints, enforce the rules, establish the relationships between entities. As XML is extensible, we can also add custom tags, custom attributes and elements as part of the XML.

We have given a sample XML representing a list of books below.

```
<?xml version="1.0" encoding="UTF-8"?>
<books>
  <book>
    <name>Gandhi: An Autobiography</name>
    <author>Mahatma Gandhi</author>
    <language>English</language>
    <genre>Autobiography</genre>
  </book>
  <book>
    <name>Letters from a Father to His Daughter</name>
    <author>Jawaharlal Nehru</author>
    <language>English</language>
    <genre>Non Fiction</genre>
  </book>
</books>
```

The XML represents a list of books where book is the main entity. The book entity is represented by a <book> tag. Various properties of the book entity such as name order and General or a presented by various attributes within the tag.

We can also define the schema for an XML. We can define various elements and the constraints for the elements using XML Schema Definition (XSD). We use XSLT (Extensible Stylesheet Language Transformations) to transform one XML document into another. We can use data type definition (DTD) for XML file validation. DTD can be used to specify the rules for the XML document; we can specify rules such as root element, nesting structure and others using the DTD.

14.2.1 XML Database

We can define the data in XML database. Given below is the representation of the students database in the table format we have to find various attributes of student such as name course taken phone number and address. Once we define the data in XML database we can use the XML parsers to read the data and query the data

using the filters and business logic. We can parse XML data into a list of key value pairs.

```
<?xml version="1.0" encoding="UTF-8"?>
<students>
  <student>
    <name>Kumar</name>
    <course>MBA</course>
    <phone>1231231234</phone>
    <address>New Delhi</address>
  </student>
  <student>
    <name>Michael</name>
    <course>MCA</course>
    <phone>1331241234</phone>
    <address>Bengaluru</address>
  </student>
  <student>
    <name>Amar</name>
    <course>MA</course>
    <phone>1331231434</phone>
    <address>Lucknow</address>
  </student>
</students>
```

Many systems store the data in the XML database. As XML format is structured and well-defined, it is also used to exchange the data across various systems.

14.2.2 XML Parsing

Parsing an XML document creates hashtable of key value pairs. The password understand the encoding used in an XML document validates the XML documents and then passes all the tax and attributes in the XML document. The parser gets the value mentioned between the tags and between the attributes. The password uses DTD for XML validation. State various rules such as the constraint validation the root element validation encoding using the DTD.

There are mainly two kinds of parsers – SAX parser and DOM parser. The SAX parser is an event-driven parser that parses the XML data sequentially. The XML tags are event sources. The SAX parser is faster as compared to the DOM parser as the SAX parser need not parse the entire document.

The DOM parser uses the document object model (DOM) which is a tree-structure representing the XML data. DOM parser parses the entire XML document as a DOM tree and stores the XML information hierarchially. DOM format supports xpath that can be used to query the hierarchical information.

Let us look at an example of SAX parser for a sample XML file

```
<students>
  <student regno="1">
    <firstname>Shiva</firstname>
    <lastname>Kumar</lastname>
  </student>
 <student regno="2">
    <firstname>Ram</firstname>
    <lastname>Krishna</lastname>
  </student>
</students>
```

The above XML file lists the details of students. To use the SAX parser we create a model class for Student entity. The model class is essentially a POJO (Plain Old Java Object) that stores the value of the student entity. In this case, we store three attributes of the student – regno, firstname and lastname.

We have given the sample SAX parser code to parse the students data in the above XML.

```
package com.example;

import java.util.ArrayList;
import java.util.Stack;

import org.xml.sax.Attributes;
import org.xml.sax.SAXException;
import org.xml.sax.helpers.DefaultHandler;

public class StudentParserHandler extends DefaultHandler
{
  //This is the list which shall be populated while parsing the XML.
    private ArrayList studentList = new ArrayList();

    //As we read any XML element we will push that in this stack
    private Stack elementStack = new Stack();

    //As we complete one user block in XML, we will push the User instance in
        userList
```

```
private Stack objectStack = new Stack();

public void startDocument() throws SAXException
{

}

public void endDocument() throws SAXException
{

}

public void startElement(String uri, String localName, String qName,
    Attributes attributes) throws SAXException
{
 //Push it in element stack
   this.elementStack.push(qName);

   //If this is start of 'student' element then prepare a new Student instance and
    push it in object stack
   if ("student".equals(qName))
   {
      //New User instance
     Student s= new Student();

      //Set all required attributes in any XML element here itself
      if(attributes != null && attributes.getLength() == 1)
      {
       s.setRollno(Integer.parseInt(attributes.getValue(0)));
      }
      this.objectStack.push(s);
   }
}

public void endElement(String uri, String localName, String qName) throws
    SAXException
{
 //Remove last added  element
```

```
    this.elementStack.pop();

    //User instance has been constructed so pop it from object stack and push in
     userList
    if ("student".equals(qName))
    {
        Student o = this.objectStack.pop();
        this.studentList.add(o);
    }
}

/**
 * This will be called everytime parser encounter a value node
 * */
public void characters(char[] ch, int start, int length) throws SAXException
{
    String value = new String(ch, start, length).trim();

    if (value.length() == 0)
    {
        return; // ignore white space
    }

    //handle the value based on to which element it belongs
    if ("firstName".equals(currentElement()))
    {
        Student s = (Student) this.objectStack.peek();
        s.setFirstName(value);
    }
    else if ("lastName".equals(currentElement()))
    {
        Student s = (Student) this.objectStack.peek();
        s.setLastName(value);
    }
}

/**
 * Utility method for getting the current element in processing
```

```
     * */
    private String currentElement()
    {
       return this.elementStack.peek();
    }

    //Accessor for userList object
    public ArrayList getUsers()
    {
     return studentList;
    }
}
```

Multiple languages such as WML, SyncML, VoiceXML etc. are XML-based languages. Mobile devices use these XML based languages for exchanging the data.

☞ **Check Your Progress 1**

1. _____ can be used to transform one XML document into another.
2. The XML rules are specified in _____
3. _____ parser is an event-driven parser
4. _____ parser uses tree-structure representing the XML data

14.3 HANDHELD DEVICE MARKUP

In this section we discuss about the HDML and WML markup languages.

14.3.1 Hand-held Device Markup Language (HDML)

Handheld device markup language is type of markup language invented for small wireless and handheld devices. The HDML is mainly used in the handheld devices like PDA, mobile phones and others.

The start tag is HDML that indicates the start of the deck. Because you specify the actions within HDML tag. Within each deck there are a list of cards that can also specify the actions. There are various kinds of card elements such as display card element, nodisplay card element and such. The detailed list of specifications can be found at https://www.w3.org/TR/NOTE-Submission-HDML-spec.html

HDML does not support scripts.

14.3.2 Wireless Markup Language (WML)

WML is XML-based W3C standard for wireless devices. Similar to XML, WML has DTD and XML-based syntax for specifying elements.WML supports script where we can code loops, procedures and conditions.

The WAP browser that runs on a mobile device renders the WML cards. Similar to a HTML page, each WML card has links, text, list and other elements as given below:

- Images
- Tables
- Anchor elements
- Formatted text
- Scripts
- Events

A sample WML deck with two cards are given below -

```
<?xml version="1.0"?>
<!DOCTYPE wml PUBLIC "-//WAPFORUM//DTD WML 1.2//EN"
"http://www.wapforum.org/DTD/wml12.dtd">
<wml>
   <card id="home" title="Home Card">
      <p>
Welcome to Home card

</p>
   </card>
   <card id="product" title="Product Card">
      <p>
Welcome to the product card
</p>
   </card>
</wml>
```

The WML deck has main cards as shown above. Each card has an id, title and the content attributes.

14.4 HYPERTEXT MARKUP LANGUAGE

Hypertext markup language (HTML) is the most popular standard for rendering internet web pages. We cannot there that a web page with all the text images and hyperlinks using them HTML standard. The term hypertext refers to jumping from one page to another through hyperlink.

We can format the HTML webpage using the style sheets. Various elements that are as input textbox list links images buttons anchors tables 2 blocks frames forms can be rendered using the HTML webpage. You can use JavaScript to inject dynamic behavior into the webpage such as event handling request-response management animation input validation form submission and so on.

Cascading style sheets (CSS) define the style specification for HTML element. For instance, the stylesheet specifies the width height alignment for an HTML element.

The most popular HTML element is the form and input type. We can use JavaScript to validate the form elements for us type validation length validation and so on.

There are primarily two types of HTML pages static web page is the one where the page content remain static until the page is edited. A dynamic web page changes the content based on attribute such as the user input, user profile and other details. We use the JavaScript to get the dynamic content for the dynamic web page.

We have depicted the sample HTML code below. All the HTML elements are declared within <body> element. The page heading is declared within <h1> tag and the image is specified with <img> tag. The table is declared using <table> tag.

```
<!DOCTYPE html>
<html>
  <body>
    <h1>Page Heading</h1>
    <p>Sample Paragraph</p>
    <img src="sample.jpg" alt="sample image" style="width:100%">
    <table>
      <tr>
        <td>Row Data</td>
      </tr>
    </table>
    <h2>Sample HTML list</h2>
    <ul>
      <li>Item 1</li>
      <li>Item 2</li>
    </ul>
    <div style="border: 1px solid black">Hello World</div>
  </body>
</html>
```

14.4.1 HTML5

HTML5 is the latest version of the HTML standard. It is enhancement over html4 that provides various instruments for multimedia edition real-time streaming and web sockets. HTML5 provides interoperable specifications for current Browsers and allows error handling features. HTML5 adds various elements for enhanced page performance and User experience and it provides enhanced forms and form controls.

HTML5 also provides audio and video HTML elements with controls for playing seeking, pausing, aborting and others. We cab also do real time streaming using HTML5 standard. HTML5 provides enhanced form and input types. The Canvas element provides the ability for 2D drawing. HTML5 also provides scalable

vector Graphics for drawing. HTML5 also provides APIs for sending and receiving messages

☞ Check Your Progress 2

1. True or False: HDML support scripts
2. HTML webpage can be formatted using the _____
3. In HTML, the page heading is specified using _____ tag
4. Dynamic content is retrieved through ____
5. Image is specified using _____ tag

14.5 SUMMARY

In this unit, we started discussing the main components of an enterprise application. We looked at various layers and the layer-wise components of enteprise application. We then discussed the XML format and the applications of the XML standard. We discussed the SAX and DOM parser for parsing the XML data. We then discussed the HDML and WML standards that is used in the mobile devices. Finally we discussed various HTML elements and the enhancements of HTML5 standard.

14.6 SOLUTIONS/ANSWERS

Check Your Progress 1

1. XSLT
2. DTD
3. SAX parser
4. DOM Parser

Check Your Progress 2

1. False
2. Cascading style sheets (CSS)
3. <h1>
4. JavaScript
5. <img>

14.7 FURTHER READINGS

References

Mobile Computing 3rd Edition by Raj Kamal -
https://www.amazon.in/Mobile-Computing-Raj-Kamal/dp/0199455414

https://www.w3.org/TR/NOTE-Submission-HDML-spec.html

UNIT 15 MOBILE APPLICATION LANGUAGES

15.0 INTRODUCTION

Mobile applications can be developed in various languages such as Java Python and others. in this chapter we will look at some of them salient features of this programming languages and sample code for developing mobile applications.

15.1 OBJECTIVES

After going through this unit, you should be able to

- understand key concepts of XML,
- understand various types of device markups,
- understand the details of WML,
- understand HTML5 standard

15.2 INTRODUCTION TO J2EE

Java is one of the most popular programming languages. Java helps us to depict Real world objects in the programming language. application developer uses the libraries provided by the software development kit additional him the programmer can also use various third party libraries and APIs to integrate with external interfaces.

There are various integrated development environment such as Eclipse, Intellij , Jdeveloper, Microsoft Visual Studio that helps developers to develop a java based applications.

The standard edition of Java is mainly used for developing the libraries and client applications. the Enterprise addition of Java (J2EE) is mainly used for developing web applications, server applications and Enterprise applications. J2EE handles the distributed applications spread across

15.2.1 Brief Overview of Java

Java is an object oriented language. the model with real world entities as Java objects we depict the state of the object using the variables. we define the behavior of the object using the methods. Java is a interpreted language and hence it runs on any operating system and any architecture (such as x86 or ARM). The JAVA SDK provides many popular libraries and API for the development. for instance the package Java total and provides the core datatypes and main classes.

The Java code is compiled into bytecodes. The Java Virtual Machine (JVM) runs the byte code on various platforms such as Linux, Windows and others.

The package java.math provides the mathematical functions. The package java.net provides the leather is for network connections; the package java.io provides input output and read write operations; the package Java dot security provides various classes for encryption decryption and other security related concerns.

Given below organ main constructs of Java:

· Class: A class is a logical unit that represents a real-world entity. A class serves as a template and groups the properties and the behavior of a real world entity in a class. The properties are depicted as fields in the class and the behavior is defined using the methods of the class. For instance a person class consists of fields such as name and phone number and behavior such as updating the phone number. An instance of the class is called an object. Object essentially encapsulates the state of the real world entity. For instance we can assign the name as Kumar and phone number as 1 2 3 1 2 3 1 2 3 4 for the person object.

·

· Method: A method is a function that depicts the behavior of the class.

·

· Bean: A bean encapsulates a key value pair in a class. We use beans to represent enmities such as database table or an entity of an XML document.

·

· Relationship between classes: There are various kinds of relationship between classes. A child class can inherit the values and behavior from its parent class. A class can also be composed of another class.

·

· Interface: The interface specified the behavior and service as a contract for implementer.

·

· Threads: Thread is a lightweight runnable object. We span multiple threads to process in parallel.

·

· Servlets: The servlets are web components that are used to render the web pages. The servlets have a lifecycle of its own.

15.2.2 N-tier Architecture in J2EE

In this section we discuss the key elements of n-tier J2EE architecture. Figure 1 depicts various tiers in a J2EE enterprise application. The presentation tier provides components such as responsive design, personalization etc. The services tier provide various services for workflow, multi-lingual services and others. The

business tier consists of business components such as blogs, search, email etc. We can have additional components related to integration, enterprise systems etc.

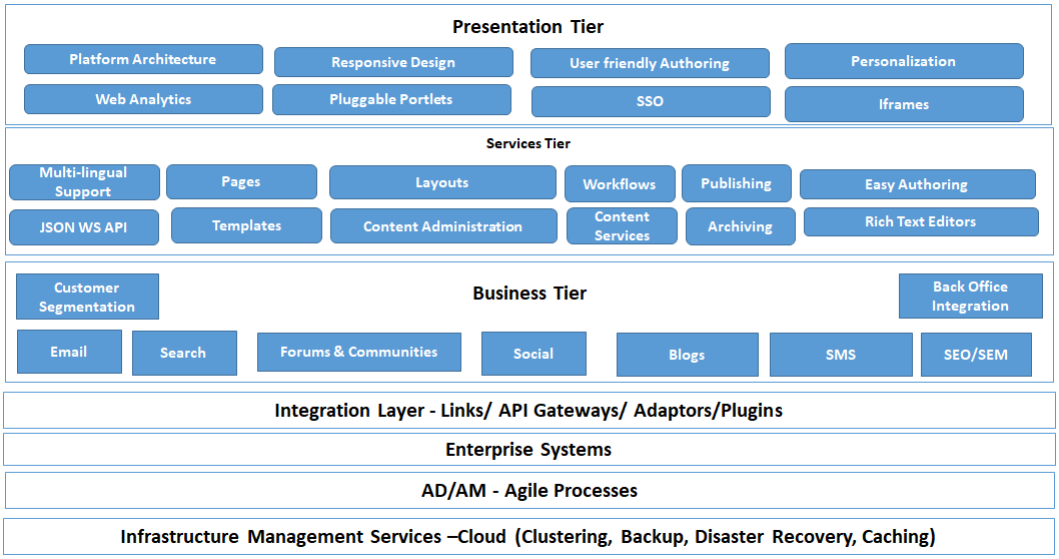


Figure 1 Sample N-Tier Architecture

We have depicted the systems view of the n-tier architecture in figure 2. Systems of interaction include the presentation components such as UI applications, analytics, caching, pages etc. Systems of differentiation include the web frameworks and core platform. Systems of integration consist of components such as API gateway, ESB and other middleware components. We have systems of record that store single source of truth for enterprise data. Systems of record include ERPs, enterprise databases and such.

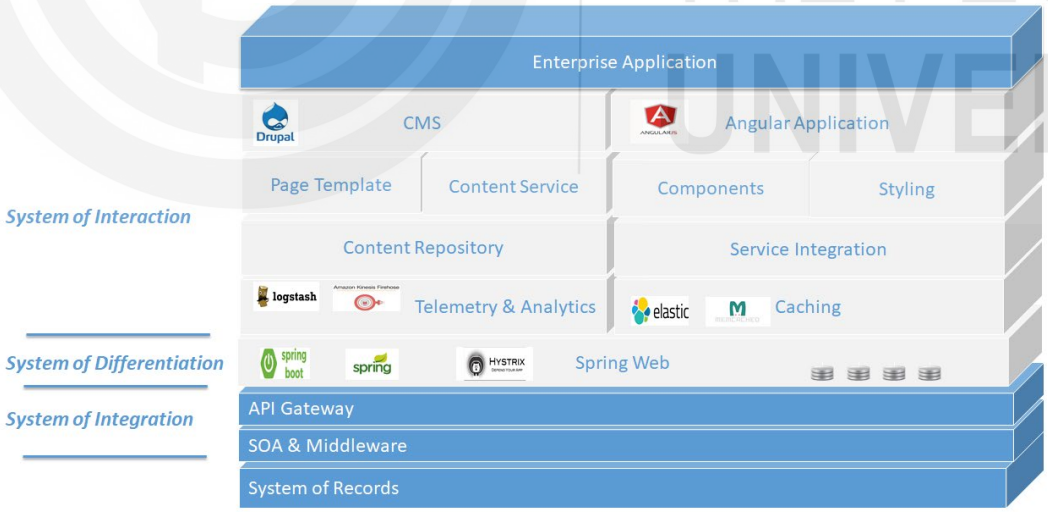


Figure 2 Systems View of the architecture

We have depicted various components involved in processing the request pipeline of the J2EE application. The request is initially handled by the cache service that provide edge-level caching. In the next step Okta-based authentication module authenticates the user. Post successful authentication, one of the functional modules (such as billing, payment, account etc.) handles the request and will leverage the components in the presentation layer.

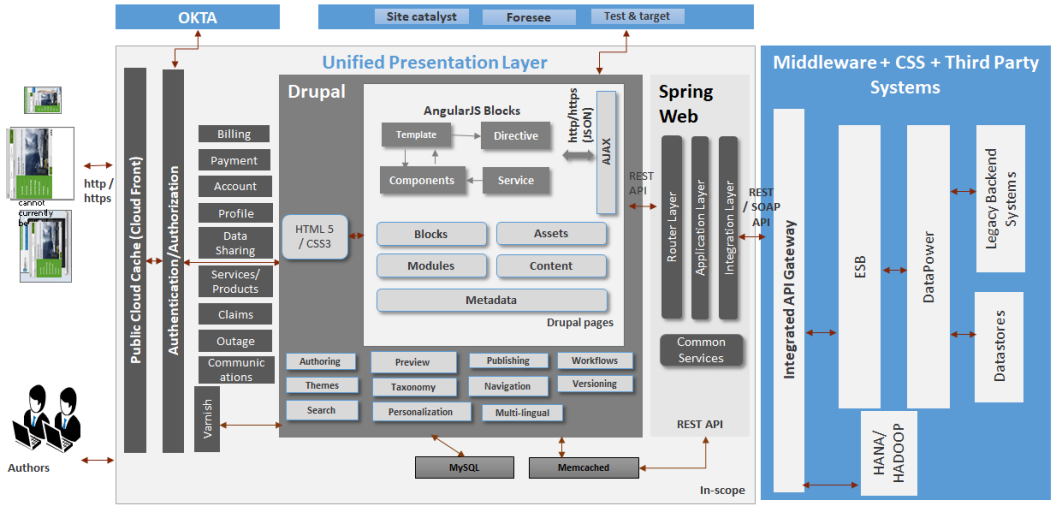


Figure 3 Request pipeline processing in enterprise application

The presentation layer modules such as HTML 5, CSS3 modules, web pages, search provide the end user experience components. The Spring web layer provides request routing, common services and REST interfaces. The service requests are then handled by the middleware systems such as ESB which retrieves data from the enterprise systems.

15.2.3 Patterns and design considerations for J2EE

Let us look at the main design considerations and advantages of J2EE.

Key advantages of J2EE

The main motivating factors/advantages of J2EE platform are as follows:

- J2EE technologies support separation of concerns by providing components and frameworks for each layer. It also separates business concerns from system concerns by providing container level services like resource management, lifecycle management. This allows the developers to focus mainly on business logic and enable to bring the solution faster to market.
- J2EE technologies support various standards such as JDBC, JSP, XML, SOAP, JMS, JNDI, Portlet, JTA and such.
- J2EE technologies support heterogeneous software and hardware avoiding vendor lock-in for the organization. It also future-proof technology roadmap as it keeps pace with technology advancements
- J2EE technologies provide robust mechanisms for session management, transaction management, security features and would provide required level of scalability and performance when configured on appropriate hardware
- J2EE technologies offer various integration mechanisms ranging from service based integration to message based integration to API based integration. This would help the organizations to easily integrate with external systems as well as in-house legacy applications.

Key design considerations for the enterprise solution

Following are the key design considerations while designing the solution:

- Extensibility: The solution should allow easy addition/extension of new functionality.
- Modularity: The solution should provide intra-layer abstraction by allowing the individual layer components to be independently modified with minimal impact on components in other layers.
- Scalable: The solution should satisfy the scalability requirements explicitly stated.
- Secure: The solution should provide security features at all levels to protect data and transaction integrity.
- Open standards: During development of integration interfaces and other components, open standards would be followed to prevent vendor lock-in.

The n-tier J2EE application typicalls uses Model View Controller (MVC) architectural pattern for a layered architecture. We have listed other common design patterns used in the enterprise application.

Design Pattern	Key design pattern	Brief Details
Presentation Layer		
	View Helper	View Helper Pattern in presentation layer for creating a custom Tag required for the solution
	Composite View	Composite View pattern in presentation layer for including JSF fragments for each page. The fragments are related to header, footer and other navigation elements to provide consistent look and feel/brand identity
	Front controller	Front controller is the single interface that handles all the web requests
Business Layer	Business Delegate	Business Delegate pattern to abstract the business service from presentation layer
	Session Facade	Session Façade Pattern to abstract the business components from the clients
	Dependency Injection/Inversion of control	Provides declarative way for defining the dependencies
Integration Layer	Web service proxy	Web service proxy pattern to invoke the internal web services like pricing system service and inventory system service to de couple the client and

		actual service details
	Business Object	Business objects encapsulate the data and operations of business entity
	Abstract Factory	The abstract factory defines the interfaces for constructing a family of related classes
	Data Access Object	The data access object (DAO) abstracts the database operations
	Service Activator for JMS	Service Activator Pattern to asynchronously receive any messages from the messaging system
Core Java Patterns		
	Singleton	Provides a single instance of the class. Mainly used to instantiate the utility class.

15.3 INTRODUCTION TO J2ME

Java 2 Micro Edition (J2ME) is the set of Java APIs that can run application on mobile devices with limited memory and resources.

The main components of J2ME are configurations and profiles. The configuration specify the minimally-required Java classes and Java Virtual Machine features required for a specific device. The configuration groups the devices with similar resource. The profile provides APIs leveraging the configuration to provide the end device's run time environment. Mobile information device profile and personal profile are two main kinds of profile used by J2ME devices. Information module profile is used for devices like vending machines, embedded systems which have no display or minimal display.

Mobile information device profile is used mainly in the mobile game development.

15.3.1 Sample Java program for file parsing

Modern applications heavily use JSON (JavaScript Object Notation) for data exchange. In a n-tier mobile application, the Java-based mobile app needs to parse and write the JSON file. In this section we discuss the sample Java code for achieving this.

Let us consider the sample JSON of student's data as given below:

```
{
   "name": "Kumar",
   "rollno": "1234",
   "course": "BA"
}
```

Given below is the sample Java code to create the JSON file in above format. In this example we have used the json library.

```
import java.io.FileNotFoundException;
import java.io.PrintWriter;
import java.util.LinkedHashMap;
import java.util.Map;
import org.json.simple.JSONArray;
import org.json.simple.JSONObject;

public class SampleJSONCreator
{
	public static void main(String[] args) throws FileNotFoundException
	{
		// Create the JSONObject
		JSONObject jo = new JSONObject();

		// populate the JSON object with the sample data
		jo.put("name", "Kumar");
		jo.put("rollno", "1234");
		jo.put("course", “BA”);

		// create the StudentData JSON file
		PrintWriter pw = new PrintWriter("StudentData.json");
		pw.write(jo.toJSONString());

		pw.flush();
		pw.close();
	}
}
```

Given below is the sample Java code to parse the JSON string

```
import org.json.JSONArray;
import org.json.JSONObject;

public class SampleJSONParser{

	public static void main(String[] args) {

		String jsonString = "{"
				+ "  \"name\": \"kumar\","
				+ "  \"rollno\": \"1234\","
				 + "  \"course\": \"BA\"
				+ "}";

		//Create the JSONObject based on the jsonString
		JSONObject studentJSON = new JSONObject(jsonString);

		//Read the JSON value
		String name = studentJSON.getString("name");
		System.out.println("Student Name: "+name+"\n");
	}
```

}

☞ **Check Your Progress 1**

1. _____ edition of Java is mainly used for developing the libraries and client applications

2. ____ addition of Java is mainly used for developing web applications

3. A ___ is a logical unit that represents a real-world entity

4. ___ encapsulates a key value pair

5. _____ provide intra-layer abstraction by allowing the individual layer components to be independently modified

15.4 INTRODUCTION TO ANDROID

Android is an open source mobile development platform. Android is based on Java programming language. Android has a huge platform ecosystem and is widely used across various mobile devices today.

Android supports various connectivity such as GSM, Bluetooth, Wi-Fi , LTE, CDMA etc. Android supports lightweight SQLite database. We can run an chrome web browser on Android. Android supports various other features such as multi touch multitasking widgets multi language etc. Android is hugely popular and it has the largest supported mobile device.

Android operating system provides many inbuilt applications such as camera alarm, calculator, contacts, email, calendar, media player, albums, clock etc. Android supports various libraries such as SQLite, SSL etc. Android runs on Linux kernel.

We can use in-built SMS Manger API for sending the SMS. A sample code snippet is shown below:

```
SmsManager = SmsManager.getDefault();
smsManager.sendTextMessage("phoneNo", null, "Test Message", null, null);
```

In Android we can use intent to pass the data from one component to another or to the external interface.

Let us look at two examples of using Intent for making a phone call and for sending out email.

Given below is the code snippet that uses the intent for making a call.

```
public class MainActivity extends AppCompatActivity {
  private Button;

  @Override
  protected void onCreate(Bundle savedInstanceState) {
    .
```

```
    .
    .

    button.setOnClickListener(new View.OnClickListener() {
      public void onClick(View arg0) {
        Intent callAction = new Intent(Intent.ACTION_CALL);
        callAction.setData(Uri.parse("tel:1231231234"));

          startActivity(callAction);
      }
    });

  }
}
```

Given below is another Android example code snippet using Intent for sending out email.

```
protected void doEmail() {

    String[] reciever = {"receiver@example.com"};
    String[] copyemail = {"supervisor@examle.com"};
    Intent emailAction = new Intent(Intent.ACTION_SEND);

    emailAction.setData(Uri.parse("mailto:"));
    emailAction.setType("text/plain");
    emailAction.putExtra(Intent.EXTRA_EMAIL, reciever);
    emailAction.putExtra(Intent.EXTRA_CC, copyemail);
    emailAction.putExtra(Intent.EXTRA_SUBJECT, "Test Message");
    emailAction.putExtra(Intent.EXTRA_TEXT, "This is a test message");

    try {
      startActivity(Intent.createChooser(emailAction, "Sending email."));
      finish();
    } catch (android.content.ActivityNotFoundException ex) {

    }
  }
```

15.5 PYTHON AND OTHER LANGUAGES

Python is a scripting language and is one of the most popular open source languages. Python is widely used in the platforms big data applications and machine learning platforms. Python provides many libraries and built-in functions for processing and data networking. Python is portable across various OS platforms.

Python supports large set of libraries including database, multimedia ,networking, graphical user interface, image processing, machine learning mobile apps, text processing, automation and so on. Python is widely used in machine learning projects using library such as keras,tensorflow, pytorch.

Let us look at an example for sending the SMS message to a mobile using Python. We can leverage various libraries such as twilio to send the SMS. Given below is the sample code snippet for sending the SMS using twilio library in Python:

```
from twilio.rest import Client
client = Client(sid, auth_token)

message = client.messages \
   .create(
       body='Sample SMS',
       from_ =  1231234123,
       to = 2451231234
    )

print(message.sid)
```

15.5.1 Swift

Swift is an open source intuitive compiled programming language designed by Apple. Swift is used in Apple iOS, devices such as Apple watch, Mac and others. Swift language uses objective C library. The Swift manages the memory automatically.

Swift provides native error handling and provides other features such as flexible enumerations, closure syntax, structs and classes.

Let us look at sample code for handling key functions in Swift

Given below is a code snippet for making a phone call in Swift -

```
func makeCall(phoneNo: String) -> Bool {
      if let pNo = URL(string: "tel://" + phoneNumber) {
         if UIApplication.shared.canOpenURL(pNo) {
            UIApplication.shared.openURL(pNo, options: [:], completionHandler:
nil)
            return true
         }

   }

   return false
}
```

For sending SMS we can leverage MFMessageComposeViewController and for sending email we can leverage MFMailComposeViewController

15.5.2 Microsoft Dot Net Framework

Microsoft.net provides various components for graphical user interface data processing data validation and SQL. languages such as C#, Visual Basic, C++ are part of the studio .NET framework. microsoft.net provides various features such

as multilingual support XML processing common language runtime and others. It provides an extensive library for database processing, Cryptography XML processing data binding web frameworks and others.

Check Your Progress 2

1. ____ can be used for sending email in Android
2. In Android we can use ____ to pass the data from one component to another
3. __ is used for developing Apple iOS applications
4. In Swift we use _____ for sending SMS.

15.6 SUMMARY

In this unit, we started discussing the main constructs of the standard edition of the Java programming language. The standard edition of Java is used for developing libraries and client applications and enterprise edition is used for developing web application and enterprise applications. For developing the enterprise applications we use n-tiered design with model view controller pattern where we create separate components in each tier handling distinct responsibility. Java micro edition is used for developing mobile gaming applications. Android is one of the most popular platforms. Android supports various connectivity such as GSM, Bluetooth, Wi-Fi , LTE, CDMA . In Android we can use intent to pass the data from one component to another or to the external interface. Using Intent we can send SMS or email within Android. Python is one of the most popular open source scripting languages. In Python we can use libraries for implementing data processing functions, Machine learning operations and for sending email, SMS.

15.7 SOLUTIONS/ANSWERS

Check Your Progress 1

1. Standard
2. Enterprise
3. Class
4. Bean
5. Modularity

Check Your Progress 2

1. SMSManager
2. Intent
3. Swift
4. MFMessageComposeViewController

15.8 FURTHER READINGS

References

Mobile Computing 3rd Edition by Raj Kamal -
https://www.amazon.in/Mobile-Computing-Raj-Kamal/dp/0199455414

UNIT 16 MOBILE OPERATING SYSTEMS AND DEVELOPMENT ENVIRONMENTS

16.0 INTRODUCTION TO MOBILE OPERATING SYSTEMS

The operating system is a system software that manages the interactions of the user with the underlying hardware. The mobile operating system is mainly designed for the mobile devices.

Mobile OS normally provides an integrated development environment, a development tool and an emulator. Some mobile OS platforms such as Apple iOS are specifically designed for underlying device and few others mobile OS platforms such as Android works across multiple mobile devices.

Mobile OS handles multiple user inputs and submit them as tasks for the underlying CPU. Often the mobile OS has to do multitasking when the user simultaneously uses multiple apps. The mobile OS essentially abstracts the hardware details of the underlying mobile device. The mobile OS also enables the end user to interact with various mobile device features such as sensors, cameras , wireless services and so on.

Many mobile OS platforms provide inbuilt apps such as cameras, contacts, messengers and so on. Android and Apple IOS for the two most popular mobile OS in the world.

16.0.1 Key concepts and functions of an operating system

In this section let us look at the key concepts of an operating system.

1. Process and Thread management

Process and thread management are one of the key functions of an operating system.

A process is a software program that runs on the CPU and uses the memory for computation. The OS allocates the CPU resources and memory resources for the process. An executing program is called process. When the process is first created it will be in the "created" state. Later on, a process moves to various States such as activated, running, suspended, deactivated and deleted state. When one process sends a message to another process, it is called "inter process communication". When the OS allocates the CPU and memory for the process, it is called a task.

The mobile OS manages both system processes and user processes. This includes creation of system processes and user processes; suspension and resumption of processes; process synchronization and deadlock handling.

A process is usually heavy weight as it needs CPU, memory and other resources. Thread is a lightweight process as it needs minimal resources. A process may consist of various threads. We normally launch multiple threads for parallel computation. Similar to a process, even a thread has many states such as creating, blocking, running, deleting, suspending and deleting.

2. Memory management

The operating system manages the system memory by allocating appropriate memory blocks for each of the processes. The memory consists of a large array of words or bytes each with an unique memory address. The mobile OS reads the sequence of words or bytes required for the process. The mobile OS also keeps track of the used memory and unused memory and prioritizes the processes that need to be loaded into the memory.

The operating system also de-allocates the memory blocks when the program has completed its job. Additionally the OS also manages the memory buffers shared memory and handles the efficient paging for the programs.

3. Device management

A device is a physical entity of the mobile. Few examples of devices are Camera, sensor, socket port or a memory buffer. The mobile OS managers the device throughout its usage life cycle. To start with, the mobile OS creates a device ID and allocates distinct memory blocks to the device. the mobile OS then opens the device for operations such as reading and writing. The mobile OS also reads the incoming data on devices such as sockets and ports. The mobile OS reads and writes the data for the device. The mobile OS also closes or de-registers the device when it is not required and deletes the memory allocated to the device.

4. File management

A file essentially stores the data as a record on the devices such as disk or flash memory. Each record has a name, descriptor and a memory block allocated to it. The mobile OS abstracts the internal storage units as files. The mobile OS manages various functions related to the file such as reading, writing, deleting,

updating and others. Optionally the files are also backed up based on the requirements. The files are organized as logical folders for easier management.

The mobile OS manages various functions of the file such as file creation, file opening, file update and file deletion. When the user wants to create a new file the mobile OS will add a file descriptor after creating a new file. The file descriptor consists of various details like the file extension, the file size and file metadata such as the creation time, permissions, author's name and so on. The OS opens the file in read or write mode. During the write mode, the program updates or adds new records.

The mobile OS also manages the security of the files and folders. Using the permission model, the OS ensures only the appropriate users with required permissions can access the files and folders.

5. Input/output management

The mobile OS manages various input/ output devices such as keyboard, printer,USB Port and others. The OS Creates a unique device ID for each of the devices and opens the device for read and write operations. The mobile OS also reads the data from the device and writes the data to the device and manages the buffer.

6. Network management

The mobile OS manages various network components such as the Wi-Fi, LTE , GSM and CDMA connectivity.

The enterprise applications would also interact with other platforms such as database and middleware platforms. The applications can use the JDBC API to interact with the database. The middleware platforms expose standards compliant API such as REST APIs, HTTP APIs, SOAP APIs and websocket APIs.

16.1OBJECTIVES

After going through this unit, you should be able to

- understand key concepts of mobile operating systems,
- understand the application programming interface,
- understand on the role of Linux for mobile devices,
- understand the end to end development process,
- understand the main development tools and emulators
- understand the key mobile OS platforms such as Android and Apple iOS and the differences between them.

16.2 APPLICATION PROGRAMMING INTERFACE

The mobile OS provides various applications and system functions for the mobile apps. For instance the mobile OS provide functionality such as call, SMS, Email, calendar, contacts and others. The mobile OS abstracts the system details and hardware interfaces through these APIs. For instance, without knowing the full specifications of the mobile camera, the mobile app developer can invoke the camera APIs for taking the pictures.

The mobile OS exposes the Application programming interface (API) for each of the system functions. The mobile app developers can use the APIs that are based on the well-defined contract.

The mobile OS also provides the APIs for creating other features such as user interface, voice based interfaces and such.

16.3LINUX FOR MOBILE DEVICES

Few mobile OS such as Apple iOS are built for specific Apple hardware devices. However Android works on vast majority of mobile devices. Android uses Linux, an open source OS that can be customized to work on various hardware devices.

Majority of the mobile device manufacturer supports Linux which can use Android. The core features such as Opera web browser, wireless features, camera, networking support are fully supported on Linux.

16.4 DEVELOPMENT PROCESS

The development process mainly consist of requirements elaboration phase, design phase, implementation phase and testing phase and deployment phase.

We have provided all the phases of the development process in Figure 1.

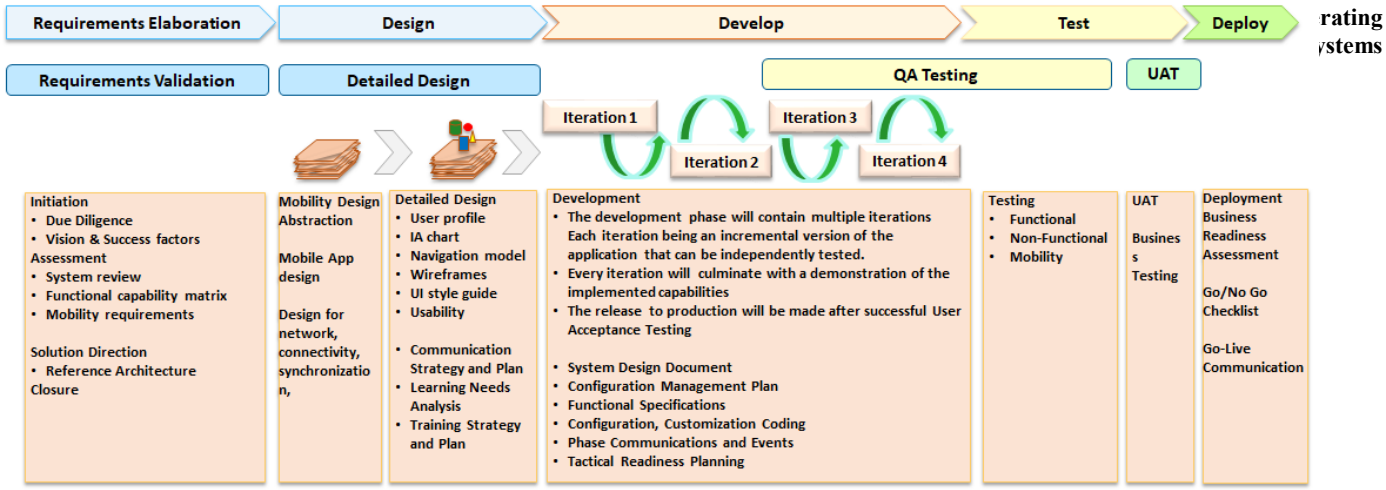


Figure 1 Phases in the development process

We shall look at each of the phases in detail.

16.4.1 Requirements Elaboration phase

We have depicted the key activities in the requirements elaboration phase in Figure 1.

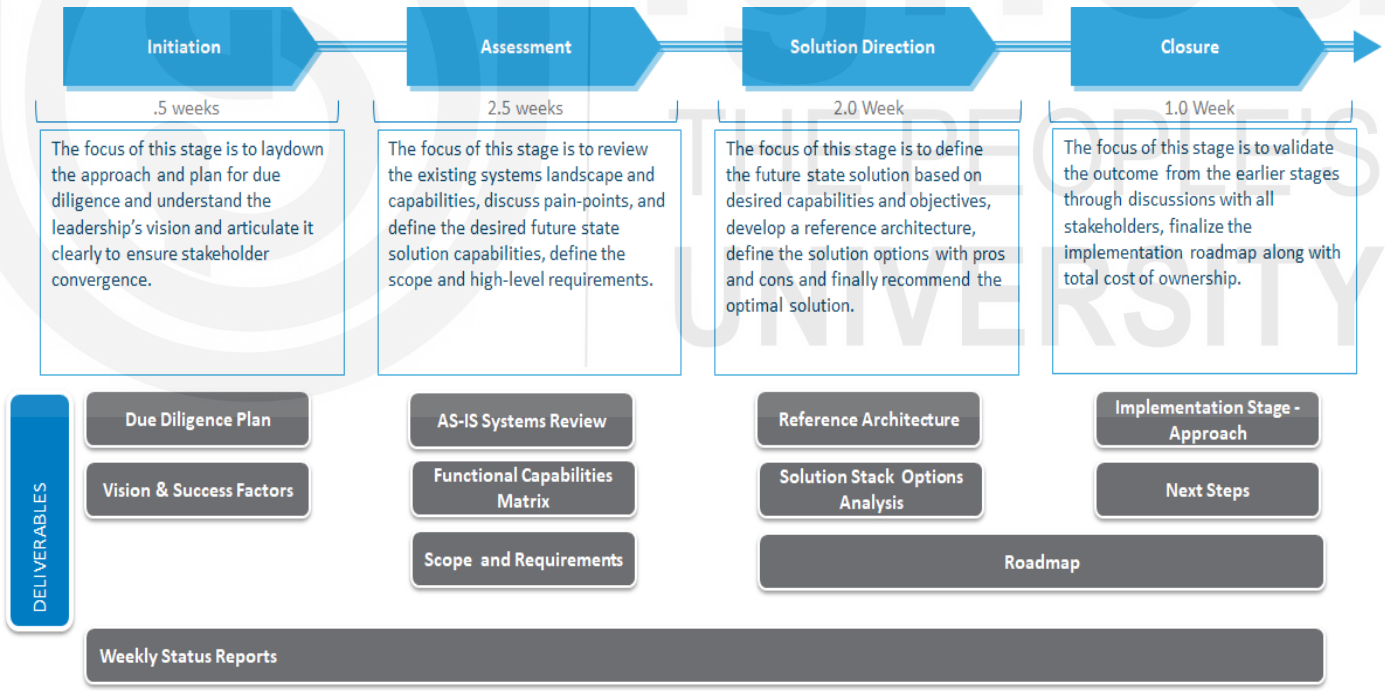


Figure 2 Requirements Elaboration Phase

During the requirements elaboration phase, we have various stages. The first stage is the initiation stage and we have given below are the main activities:

- Discuss and finalize the detail plan for the 6 week assessment
- Meet the program leadership to understand their vision for the future state
- Understand the pain-points from the current solution, discuss/document the key success factors for the future state solution.
- Meetings/Interviews with the business stakeholders to understand the short & long-term objectives of the solution

- Create a list of all internal and external systems for integration, and the key stakeholders to be included as a part of the future state planning meetings

The main deliverable from this stage are as follows:

- Detailed Project Plan
- Vision, and Key Success Factors

The next stage is the assessment stage where we do the assessment of the current technical eco-system. Given below are the key activities in this stage:

- Assess the as-is technical environment to understand the current solution, technologies, customizations, integrations etc. spanning portal, content management, search, social networking and backend applications.
- Meetings/interviews with business and IT stakeholder to understand the business functional capabilities for the future state
- Assess the key mobility related capabilities:
    - The type of mobile devices to be supported
    - The form factor of the mobile devices
    - Understand various constraints such as network/bandwidth constraints
    - Understand the multi-lingual capabilities required for the mobile device
    - Understand the various networks that need to be supported such as GSM, Wi-Fi, CDMA, GPRS etc.
    - Understand various connectivity requirements
- Understand various data sources and user inputs such as multi-touch inputs, gestures, face recognition, biometric authentication and such.
- Understand the data integration requirements such as Email server, SMS server etc.
- Develop the capability matrix for the following functional areas -
    - Mobile capabilities
    - Content Management
    - Search
    - Social networking and collaboration
    - Integration requirements
    - Personalization
    - Tasks & Workflow management
- Develop the high-level scope and requirements for the future state solution
    - Functional grouping and segregation
    - Business value driven initial prioritization on the grouped functionalities

The deliverable of this phase are as follows:

- As-is systems review document
- Functional Capability Matrix, Groupings and Prioritization
- High-Level Scope and Requirements documentation

We evaluate and shortlist various solution options n the solution direction phase. Given below are the key activities in this stage:

- Confirm the relevance of various planned and in-flight programs critical for the success of this program. Example: dependency on external systems

- Develop the reference architecture based on the high-level scope and requirements and determine dependencies.
- Identify & finalize the future state solution stack options for the mobility solution. Evaluate the native mobile app along with hybrid mobile app. Identify all related and dependent products/frameworks required for the solution.
- Define and document the pros & cons for the solution options, and provide recommendations – both for hardware and software.
- Define the total cost of ownership – based on license fee, implementation and support cost.
- Develop the implementation roadmap based on the recommended option, and mark out the dependencies

Given below are the deliverable of this phase:

- Reference Architecture
- Solution Options, and Recommendations (including TCO analysis)

In the last step of closure, we provide the recommendations and given below are the various activities:

- Present summary of the findings so far – validate with stakeholders
- Discuss, and finalize the solution option for the implementation phase
- Complete the implementation roadmap, timelines and dependencies
- Close out *the* stage
- Develop the implementation roadmap based on the recommended option, and mark out the dependencies

Given below are the deliverable from this stage:

- Implementation Roadmap
- Final set of deliverables as detailed in the prior stages

16.4.2 Design phase

During design phase we do the solution design. The key design principles are as follows:

1. Creating decoupled components
2. Creating modular components
3. Designing components that have lower coupling
4. Creating components based on single responsibility principle.

The main activities in the design phases are given below

User Research

- Stakeholder interviews to understand business goals, user profiles, needs, and pain points
- Working sessions with actual users as identified by business stakeholders
- Prioritization of user scenarios & user profiles

Conceptual Design

- Information architecture
- Navigation flows
- Task flows
- High-level wire-frame for scenario

Detail Design

- Interaction and Interface design for identified scenarios in wire-frames
- Iterative design with feedback from business team

Visual Design

- Depiction of end-state visual design of unique page types with brand guidelines.
- We also design the screens for various mobile device form factors

Mobile app core design

This includes the design for various connectivity types and for data synchronization.

Integration Design

We design the most appropriate integration methodology for various data sources such as enterprise applications, web services, databases and such. We also design the strategy for caching, data synchronization and such

The main deliverable from this phase are as follows:

- User profile documentation
- IA chart
- Navigation model
- Wireframes for selected user scenarios
- Static JPG images of visual design for unique page types
- UI style guide document

The detailed steps in the visual design is depicted in Figure 3

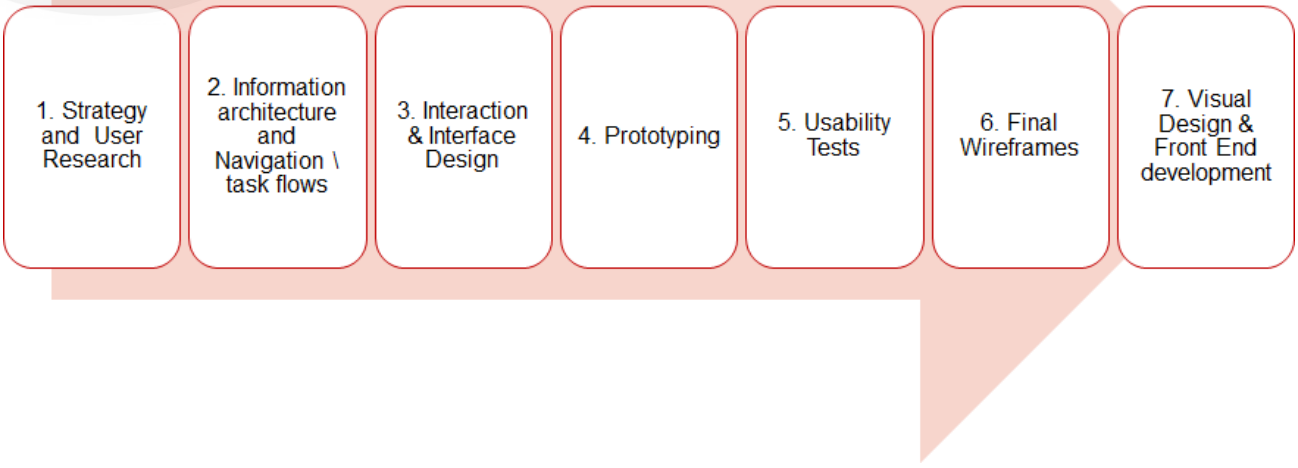


Figure 3 Visual Design Steps

The main deliverable of the user interface design is depicted in figure 4.

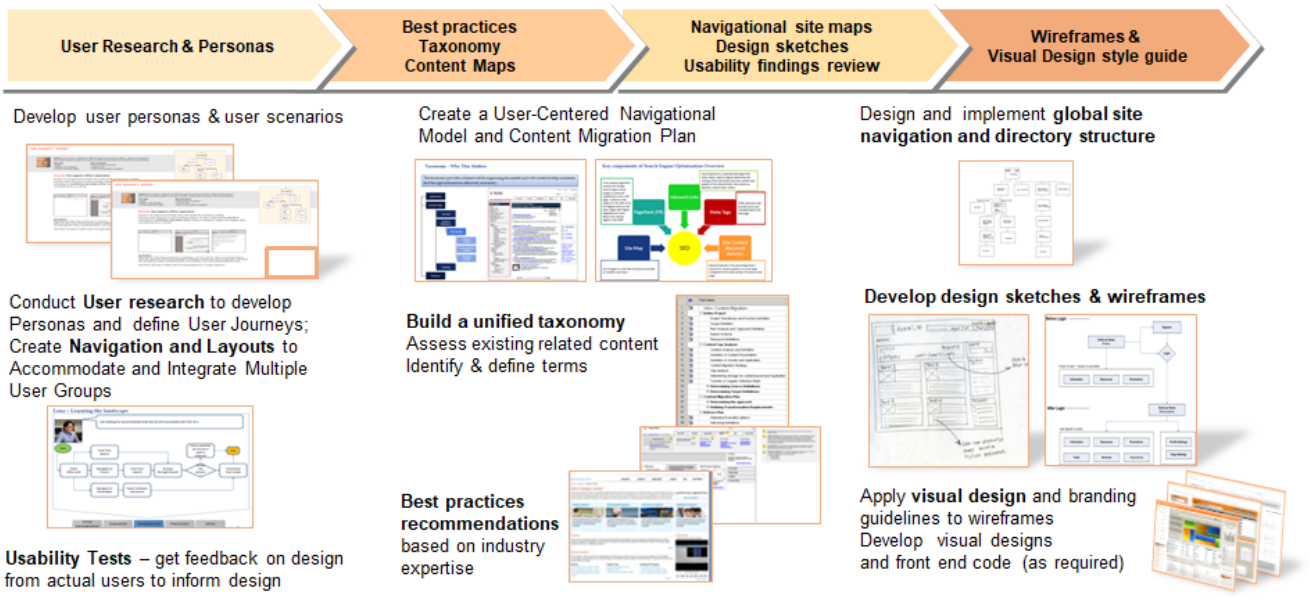


Figure 4 User interface design deliverable

We develop the user personas, taxonomy and content maps and best practices. We also develop the sitemap and usability findings. Finally we design the wireframe and visual design and style guides.

16.4.3 Implementation/Develop phase

The main activities during the implementation phase are as follows:

- Requirement gap analysis
- Gathering AS-IS security architecture, external applications
- Finalizing business rules
- Finalizing pseudo code and other documentation
- Finalizing integration points with other application
- Detailed system design
- Convert the design into complete system
- Versioning and source control
- Unit test case execution
- Assisting in Installing and setting up various environments
- Creating and testing databases as per scope
- Preparing unit test case procedures
- Coding & Compiling
- Performing test readiness review
- SSO integration & web- services.
- Content creation (static contents, templates, workflows)

The main deliverable from the implementation phase are as follows:

- Detailed System Design Document
- Configuration Mgmt. Plan
- Detailed Project Plan
- Configuration, customization coding and deployment
- Completion of project documentation
- Creation of manual document

- Deployment Guide

16.4.4 Testing phase

During the test phase we validate the functionality. We test the mobile app across all supported devices of various screen sizes and mobile OS platforms. Given below are the main activities of mobile testing:

- Requirement gap Analysis
- Business Scenarios gathering
- Create a Test Plan
- Creating Functional Test Cases
- Requirement Traceability Matrix
- Test Data Identification
- Test Execution
- Defect Management
- Status Report

16.4.5 Deployment phase

During this phase we deploy the mobile app to the mobile device and test the functionality. We test the mobile app functionality based on various user inputs. We also test the security and performance of the application on the actual device.

We test the screen usability across various screen sizes. Also we test the error handling capability of the app.

16.5 DEVELOPMENT TOOLS AND EMULATORS

Various integrated development platforms and emulators can be used for mobile app development.

Integrated development platforms provide various tools and services to boost the developer productivity for mobile app development. Integrated development environment provides all the features required for a developer in a single place. given below are the main features of a typical integrated development platform:

1. Source code editor: The visual editor of an IDE provides various features for developers searches autocomplete, Syntax highlighting code refactoring code snippets etc.
2. Code Compilation: The IDE compile the source code into binaries
3. Plugins: The IDEs provide various plugins for support specific deployment types, framework development and others.
4. Code debugging: The IDE allows developers to debug the code through various features such as stepwise execution variable value inspection and so on
5. Package and build: The IDE Provides features for building the code and packaging the code into deployable artifacts.
6. Integrated source control: The IDEs provide seamless feature to check out and check in the code from the source control systems.

Besides these the IDEs provide various other features such as search in files, boiler plate code, auto generation of code and such.

Visual Studio is one of the most popular tools for developing dot net applications. Android studio is the preferred tool for developing Android mobile applications. IntelliJ IDEA, Cordova, Eclipse, NetBeans are other popular IDEs.

Emulators are virtual devices that let developers test their mobile apps on various mobile devices.

Android studio is one of the most popular integrated development environments for Android mobile app development. The Android studio is free and provides smart code editors code Bin systems code profiling systems visual code editors to boost them developer productivity Android studio also provides emulators for testing the Android based mobile apps on various devices Andy, BlueStacks, Manymo, Xamarin, Visual studio Emulator are other competitors for Android development.

XCode is an integrated development environment for developing Apple iOS apps. Al can use XCode to develop apps for Apple Mac, Apple watch Apple iPad and Apple TV. Hex code provides an intelligent source code editor and the visual builder. the tool also provides code compiler code debugger and simulator.

☞ Check Your Progress 1

1. A ____ is a software program that runs on the CPU and uses the memory for computation
2. ____ is a lightweight process as it needs minimal resources
3. The mobile OS exposes the _____ for each of the system functions.
4. The five phases in the development process are _____
5. The solution design happens in _____ phase.
6. _____ are virtual devices that let developers test their mobile apps on various mobile devices.

16.6 APPLE iOS

Apple iOS 15 is the latest version of the I was that runs on various devices like Mac iPhone and iPad. Apple devices are immensely popular for the sleek design, highly intuitive user interface and for its performance. The key features iOS 15 or given below:

- Face ID recognition that unlocks the iPhone using user's face.
- FaceTime that allows users to connect and share with their friends and family and watch movies on their iPhone devices. The SharePlay allows users to share the movies and music during the FaceTime chat with their friends and family.
- Enhanced messaging where users can share the messages with their friends and family members.
- Customizable Memoji using colors glasses, colored headwear and other features.

- Enhanced focus and notification feature. The feature provides the users with focus time through do not disturb mode while doing activities such as reading, driving, fitness, sleep etc.
- Enhanced maps that provide interactive view of City for easier navigation
- Enhanced Safari browsing experience through tab groups, customizable start page, tab group synching, refresh by pull, voice search and others.
- Enhanced speech processing through Siri
- Enhanced accessibility features at libraries for Augmented reality, camera , gaming , keyboards , music notes, reminders, fonts, translate widgets and others.
- Enhanced gaming features such as multi-player games, game highlights,
- Enhanced camera features through improved Panorama pictures.
- Other intuitive features such as Live Text, Wallet, Spotlight, Photos, Health, Mail, Privacy, Apple ID, accessibility, App library, App store, CarPlay, dictionaries, keyboard dictation, translation, voice memos and others.

Apple iOS uses Swift, Cocoa and Cocoa touch for developing user interfaces. Apple iOS runs on Apple's ARM based chip. Safari is the default web browser on Apple IOS. Apple Safari supports multiple advanced features such as search, bookmarks, web suggestions, HTML5 autofill forms, OCR, web and native integrations. Apple iOS supports various network connectivity such as GSM, EDGE, Bluetooth, Wi-Fi, 3G, 4G and others.

Apple devices are known for highly intuitive and user-friendly interfaces. iOS supports personalized home screen, multi touch features, virtual keyboard, configurable widgets autocomplete, live wallpapers and others. IOS device drivers provide interfaces to various devices such as Global positioning system, accelerometer, magnetometer, camera and others.

Apple iOS also supports multitasking features. Users can switch across various iOS apps and work with them simultaneously. Apple uses iCloud for storing the user photos and media.

Developers can use IOS SDK for various activities such as database processing, XML parsing and so on.

16.6.1 IoS Architecture

The Apple iOS architecture consist of various layers as depicted in Figure 5. We primarily have user interface layer, media layer, core layer and kernel layer. Each layer has a distinct responsibility.

The user interface layer includes components that provide various user interface features such as touch, pinch, drag and others. The App Kit and touch framework handle the user inputs and gestures. We also have various apps like chat, email, FaceTime, Apple Pay and widgets like calendar, weather, stock quotes and others.

The media layer includes components to render images, video and other media files. We have libraries to render 2D graphics, 3D graphics, animation and others.

The core layer provides the foundation services, phone services, cloud services, sharing services and others. The kernel layer interfaces with the hardware and provides networking services. The networking services supports various network types such as Wi-Fi, NFC, CDMA, 4G etc. The device drivers provide interface to storage devices and USB ports.

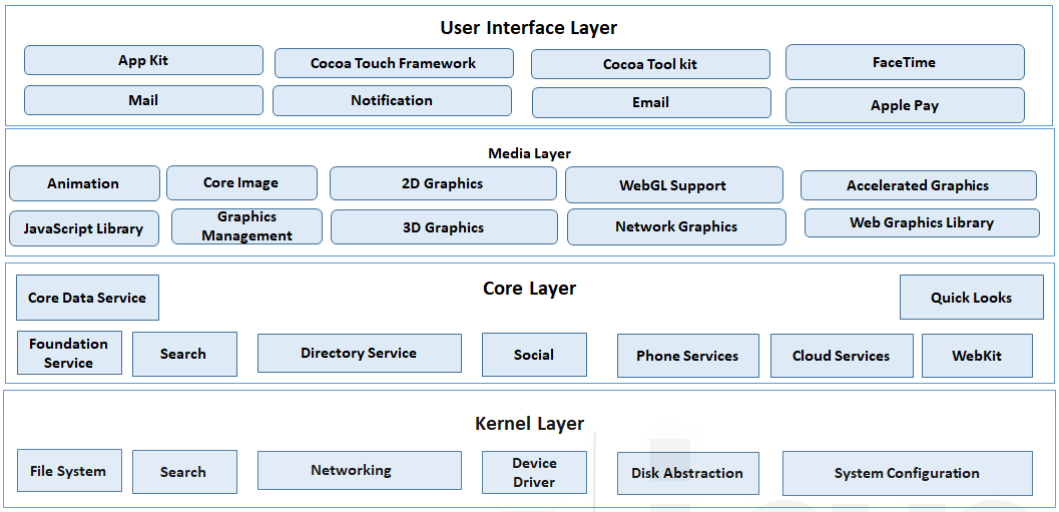


Figure 5 Apple iOS architecture

16.7 ANDROID

Android is one of the most popular mobile platforms and uses Linux. The Android code runs on Dalvik virtual machine Which is designed for mobile devices. Java programming language can be used for developing Android apps. java being an interpreted language its platform Independent and hence runs on the virtual machine. Android uses modified Linux kernel, licensed Apache server. Various device manufacturers such as Samsung, HP and others modify Android for their devices.

Android 12 is the latest release of Android. it provides a personalized experience for users so that they can use personalized widgets and personalize their home page. Android 12 provides refreshingly new design and responsive UI for the user interfaces. Android 12 supports accessibility features such as area magnification, bold text, grayscale and others. Android 12 he is also more secure and Protects user Private data. Android 12 also supports various enhancements that has camera access control, location security, privacy settings and others. it also offers again mode for richer gaming experience.

16.7.1 Android Architecture

We have depicted the Android architecture in Figure 6.

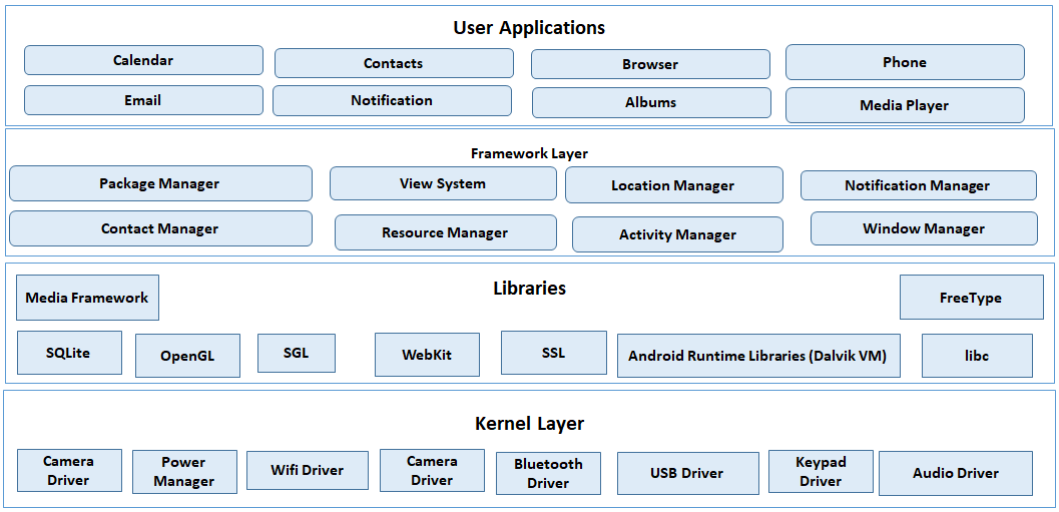


Figure 6 Android Architecture

Kernel Layer

Linux Kernel abstracts the hardware and provides all the device drivers for devices such as camera, keypad, USB, display device and others. Linux Kernel also handles the networking functionality. The kernel also handles the power and resource access.

Libraries

On top of Linux Kernel, we have various libraries such as the web browser webkit, libc (C Runtime library), OpenGL, FreeType for font rendering, SQLite database library, SSL library for handling the security, Surface manager for rendering windows and media framework for handling audio video and other media files.

Android also provides various input libraries for developers:

- android.app is a fundamental library provides access to application model
- android.content provides content management features such as content access, content publishing and messaging
- android.database provides database access features
- android.opengl provides 3D graphics rendering APIs
- android.text provides APIs for handling text
- android.webkit provide web browsing features

Android runtime includes Dalvik virtual machine which is optimized for Android. Dalvik VM uses Linux memory management and process management. Dalvik VM is optimized for mobile devices as it consumes less memory and has high performance.

Framework Layer

Application Framework layer provides high level API for the Android apps. Given below are the key services:

- Resource manager provide access to the color settings, user interface, layouts and other resources we use in the application.
- Notification manager helps in display alerts and notification
- Activity manager controls the application life cycle activity

- Content provider helps in publishing and sharing the data across applications
- View system helps in creating the user interfaces
- Telephony manager for managing the voice calls
- Location manager for managing the locations, GPS and cell towers

The layer also provides various APIs for locations, telephony, package management and others.

User Applications

We can develop number of Android apps such as ebook reader, games, SMS, calendar, browser using the application framework.

16.8 DIFFERENCES BETWEEN IOS AND ANDROID OPERATING SYSTEMS

Given below are the main differences between Android and iOS:

Category	Android	Apple iOS
OS Family	Linux	Unix, OSX
Source Model	Open Source	Commercial
Development Framework	Java	Swift
App Store	Google Play Store	App Store
Maps	Google Maps	Apple Maps
Voice Assistant	Google assistant	Siri
Data sharing and backup	Bluetooth	iTunes
Cloud Support	Google Drive	iCloud

Check Your Progress 2

1. _____ unlocks the iPhone using user's face.
2. ____ that allows users to connect and share with their friends and family and watch movies on their iPhone devices.
3. The ___ layer includes components to render images, video and other media file in Apple iOS
4. Android code runs on ____ virtual machine Which is designed for mobile devices.
5. _____ provides content management features such as content access, content publishing and messaging in Android

16.9 SUMMARY

In this unit, we started discussing the core concepts of the the OS. We looked at the key functions of mobile OS such as process management, memory management, device management and others. We also looked at the application programming interface exposed by the OS. We studies the five key phases of the development process including the requirements elaboration phase, design phase, implementation phase, testing phase and deployment phase. We studied various

IDEs and emulators such as Android Studio, Xamarin, Visual studio and others. We understood the key features of Apple iOS 15 such as Face ID recognition, FactTime, enhanced camera and others. We also looked at various layers of the Apple iOS architecture such as user interface layer, media layer, core layer and Kernel layer. We looked at the main features of the Android 12 OS. We studied the Android architecture consisting of various layers such as user applications layer, framework layer, libraries and Kernel layer. We finally looked at the main differences between Android and Apple iOS

16.10 SOLUTIONS/ANSWERS

Check Your Progress 1

1. process
2. Thread
3. Application programming interface (API)
4. Requirements elaboration, design, develop and testing and deployment
5. Design
6. Emulators

Check Your Progress 2

1. Face ID
2. FaceTime
3. media
4. Dalvik
5. android.content

16.11 FURTHER READINGS

References

Mobile Computing 3rd Edition by Raj Kamal - https://www.amazon.in/Mobile-Computing-Raj-Kamal/dp/0199455414