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 Even though a lot of techniques get outdated, their basis are often used to make enhanced devices for communication.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

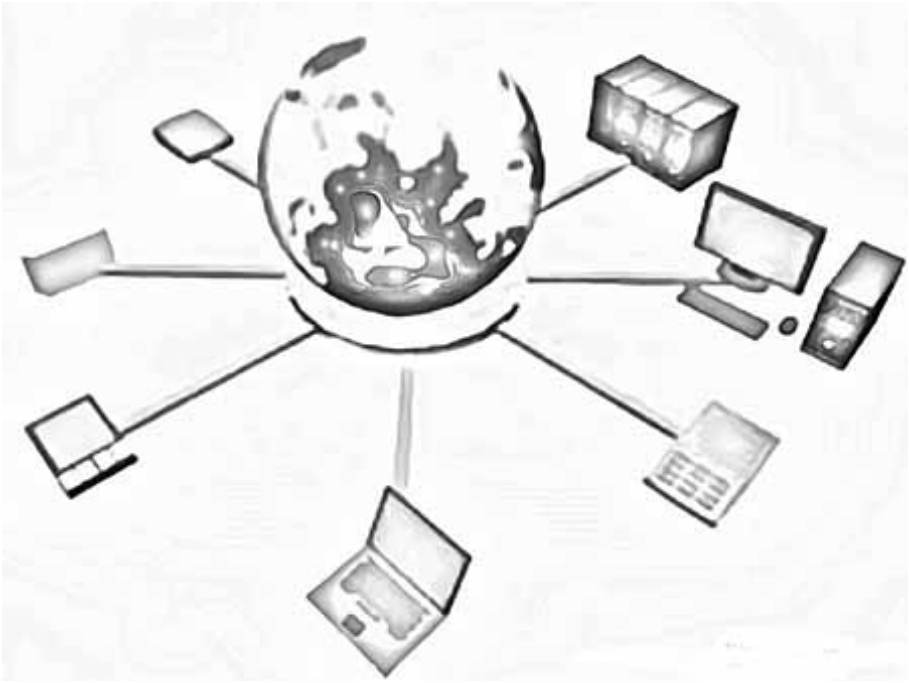
At the end of this Unit, you shall be able to:

(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.

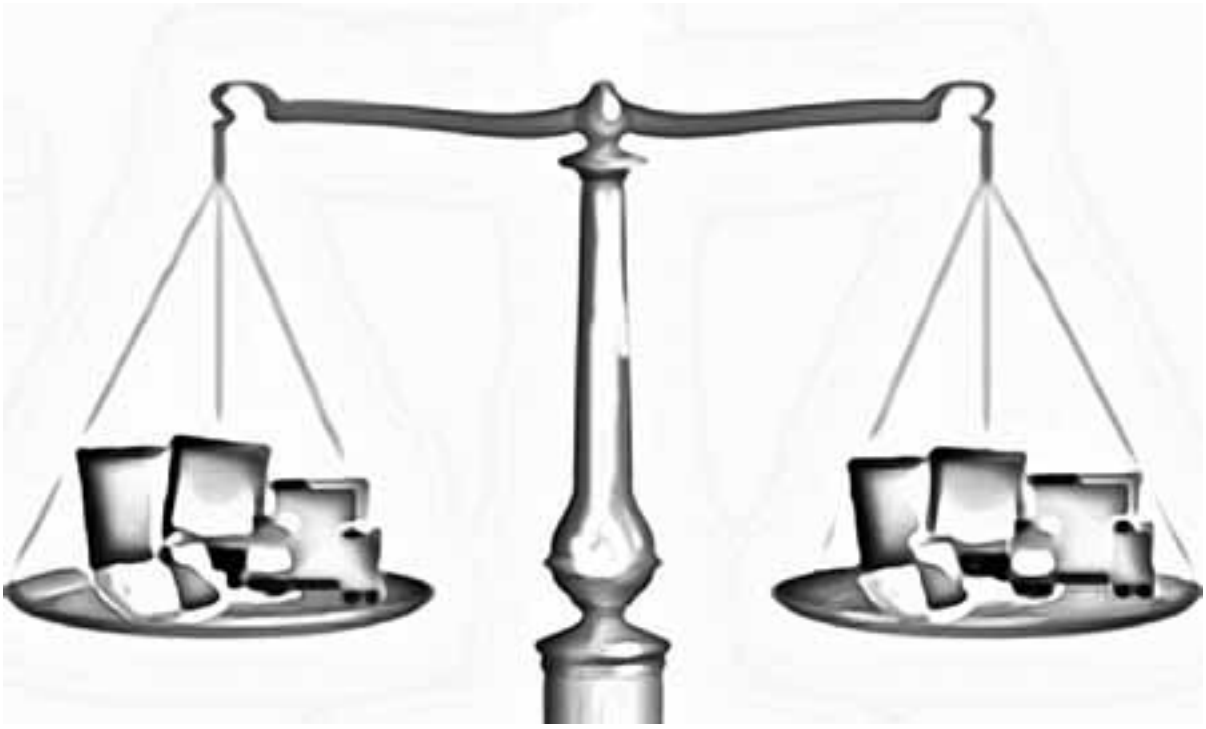
1.2.2 Device Mobility

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.

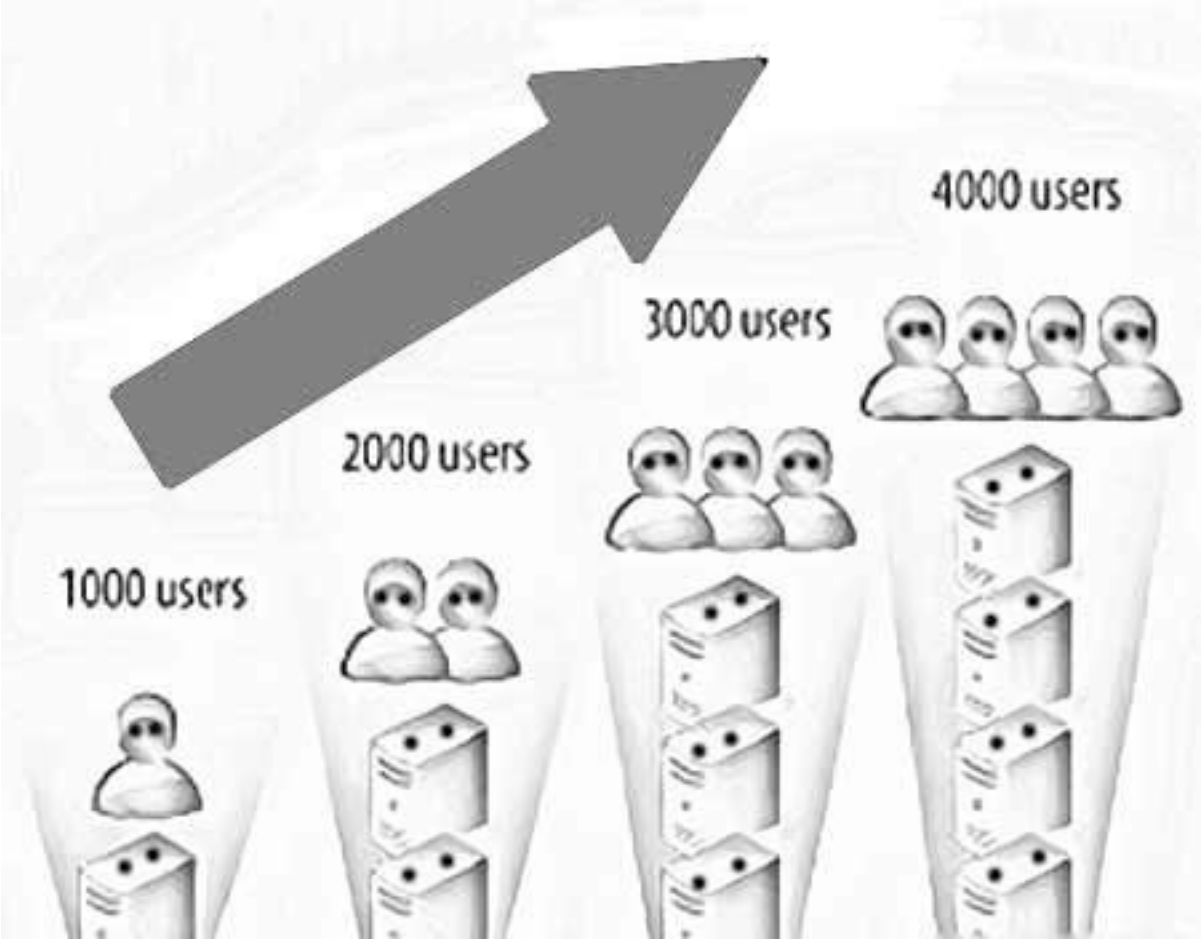
1.3 FEATURES OF MOBILE COMMUNICATION

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

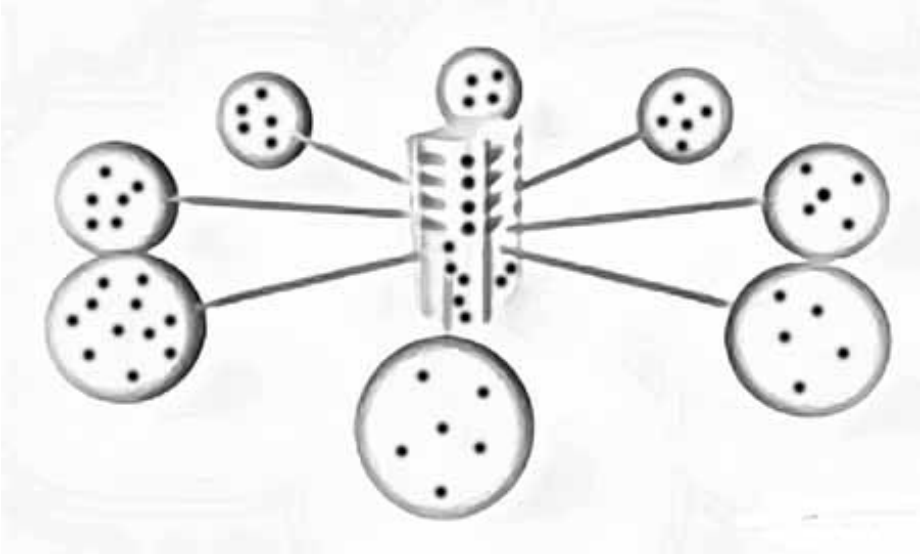
When one access point is overloaded, the system will automatically choose a different access point based on the available capacity.



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.

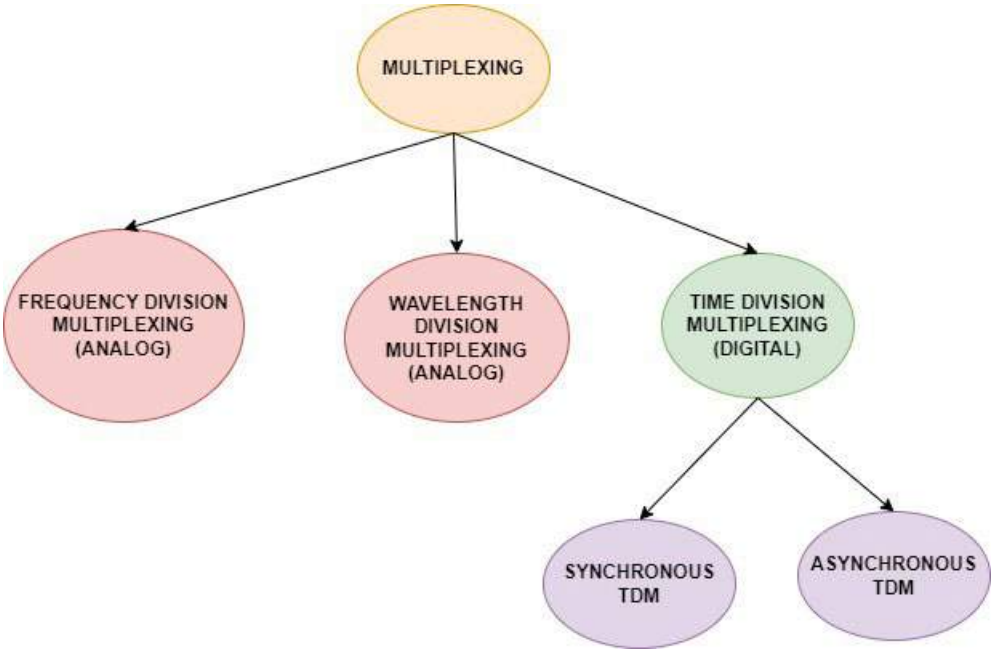
An example of multiplexing is how multiple calls can be connected through one telephone wire.

Types of Multiplexing

1. Frequency Division Multiplexing (FDM)

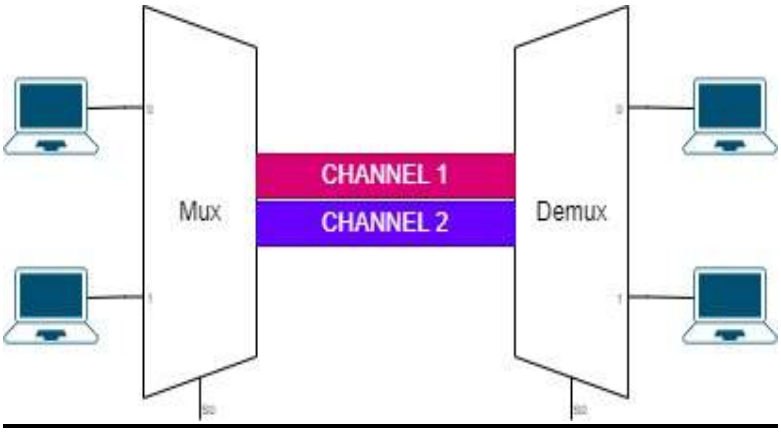
2. Time Division Multiplexing(TDM)

3. Code Division Multiplexing(CDM)



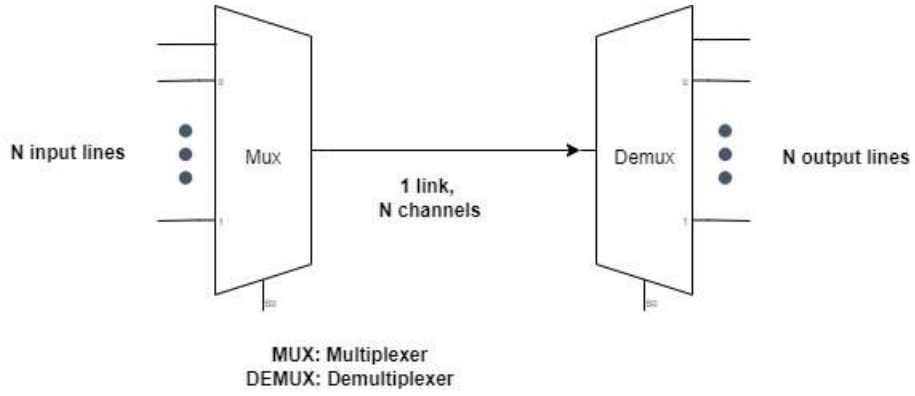
1.4.1 Frequency Division Multiplexing (FDM)

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.

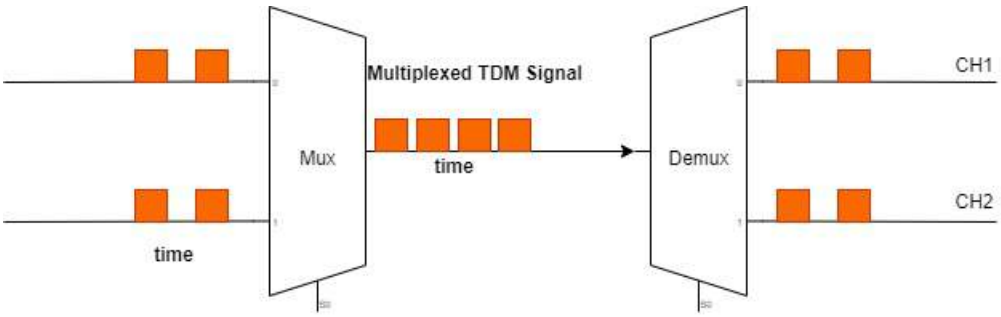
1.4.1.3 Applications of FDM:

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.



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:

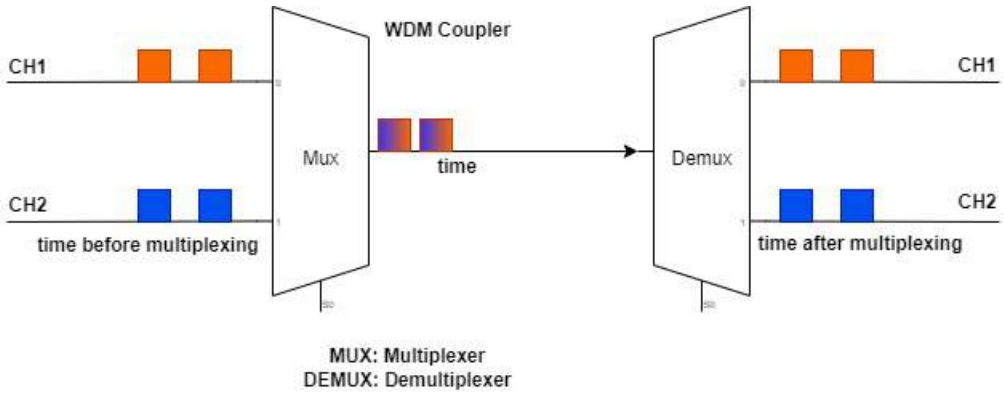
1. Synchronization is required.
2. The implementation is complex.
3. Slow narrowband fading may wipe out all TDM channels.

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.

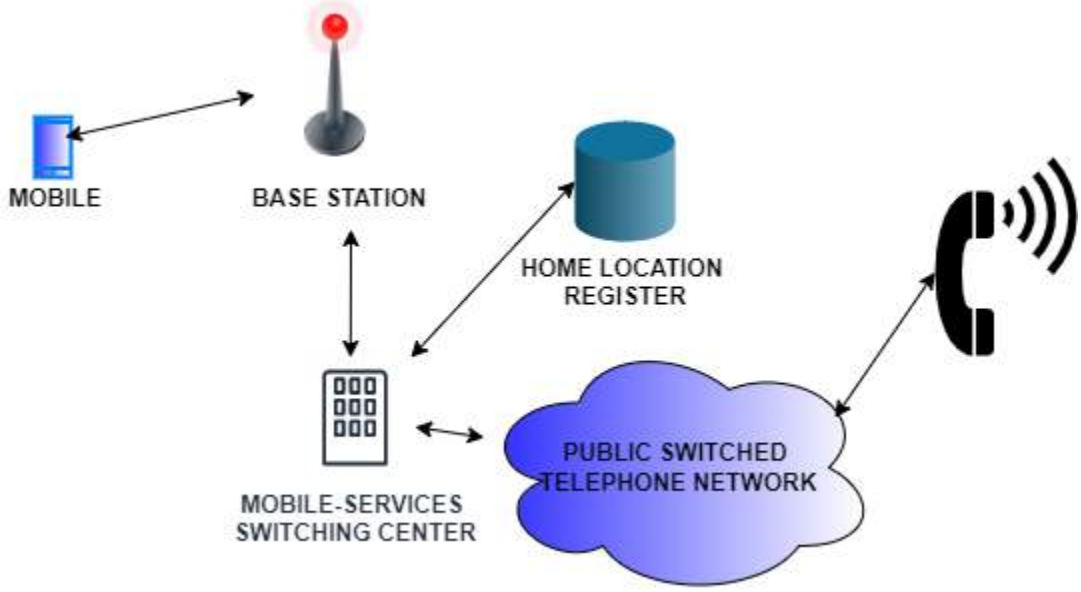
1.4.3.3 Applications of WDM:

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.

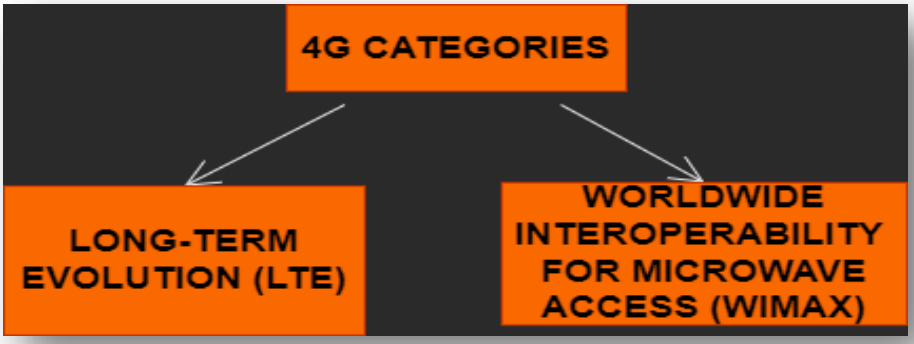
1.9 LONG-TERM EVOLUTION (LTE)

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.

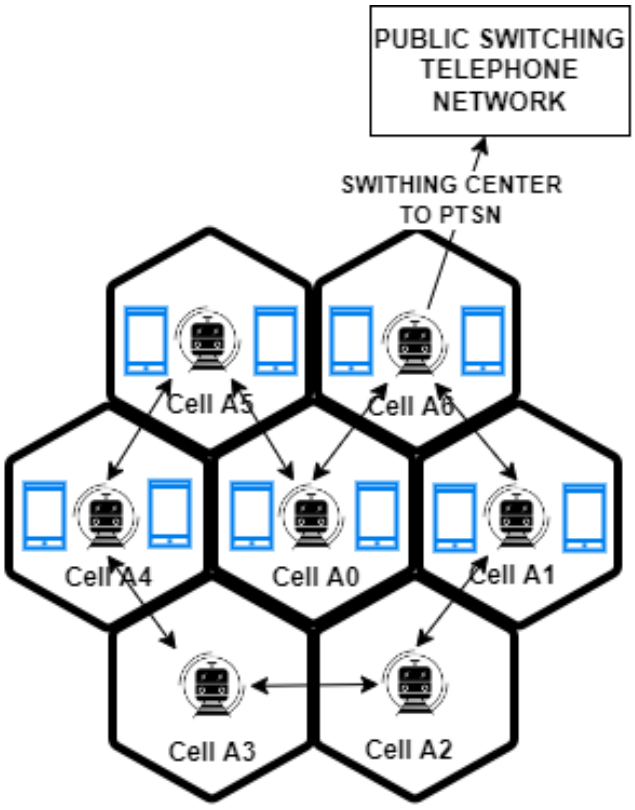


Fig 1: Mobile communication using the cells A1, A2, A3, A4, A5, and A6 of a cellular network

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.

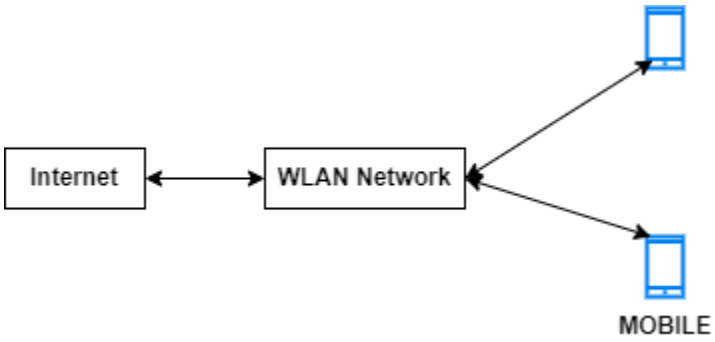


Fig2: 802.11 WLAN communications

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.

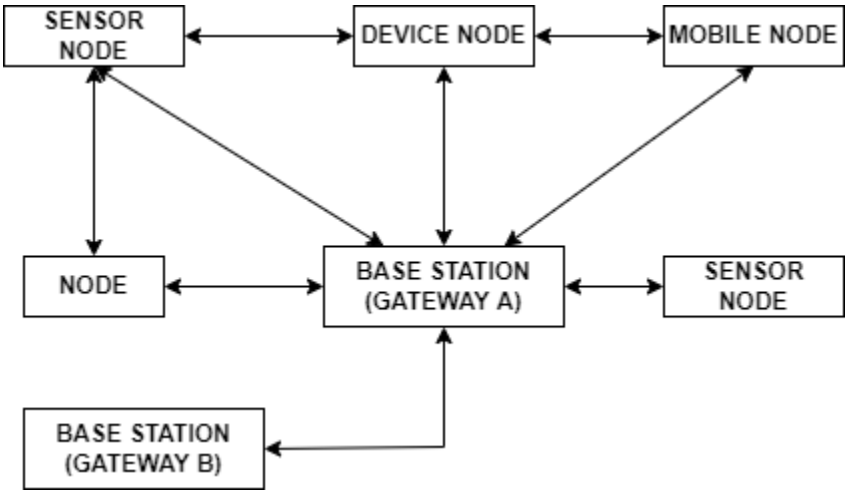


Fig3: Direct communication between sensor nodes and mobile nodes utilizing a base station as a gateway

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.

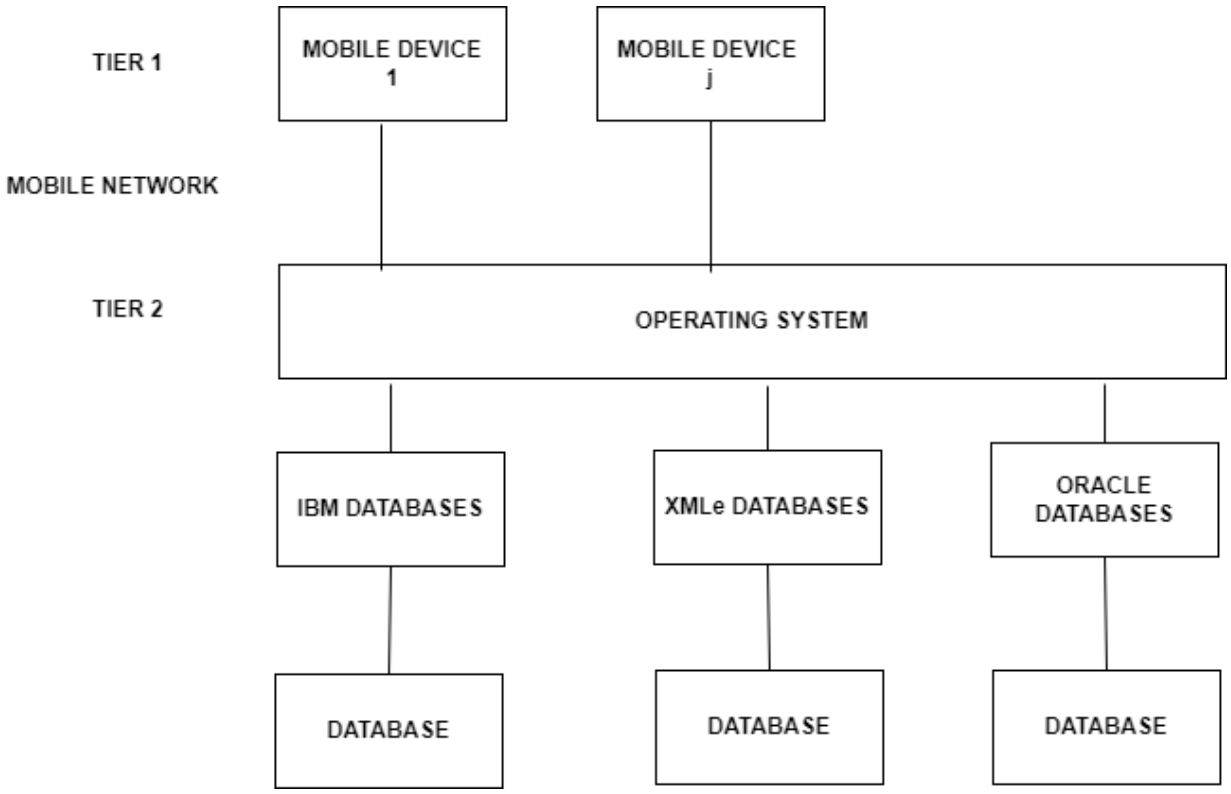


Fig 4: Two-tier client server application

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.

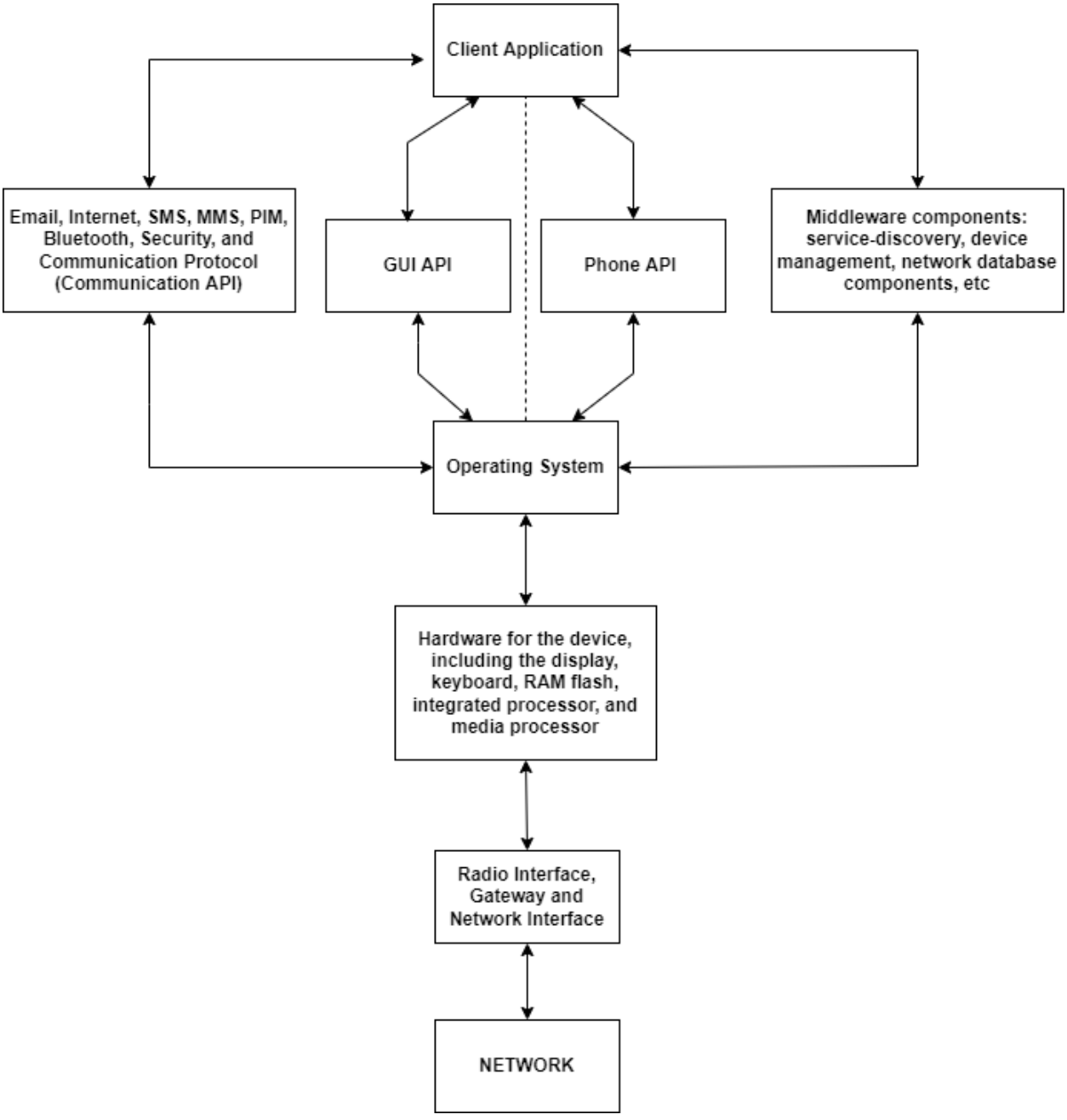


Fig 5: Mobile Computing Architecture

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.

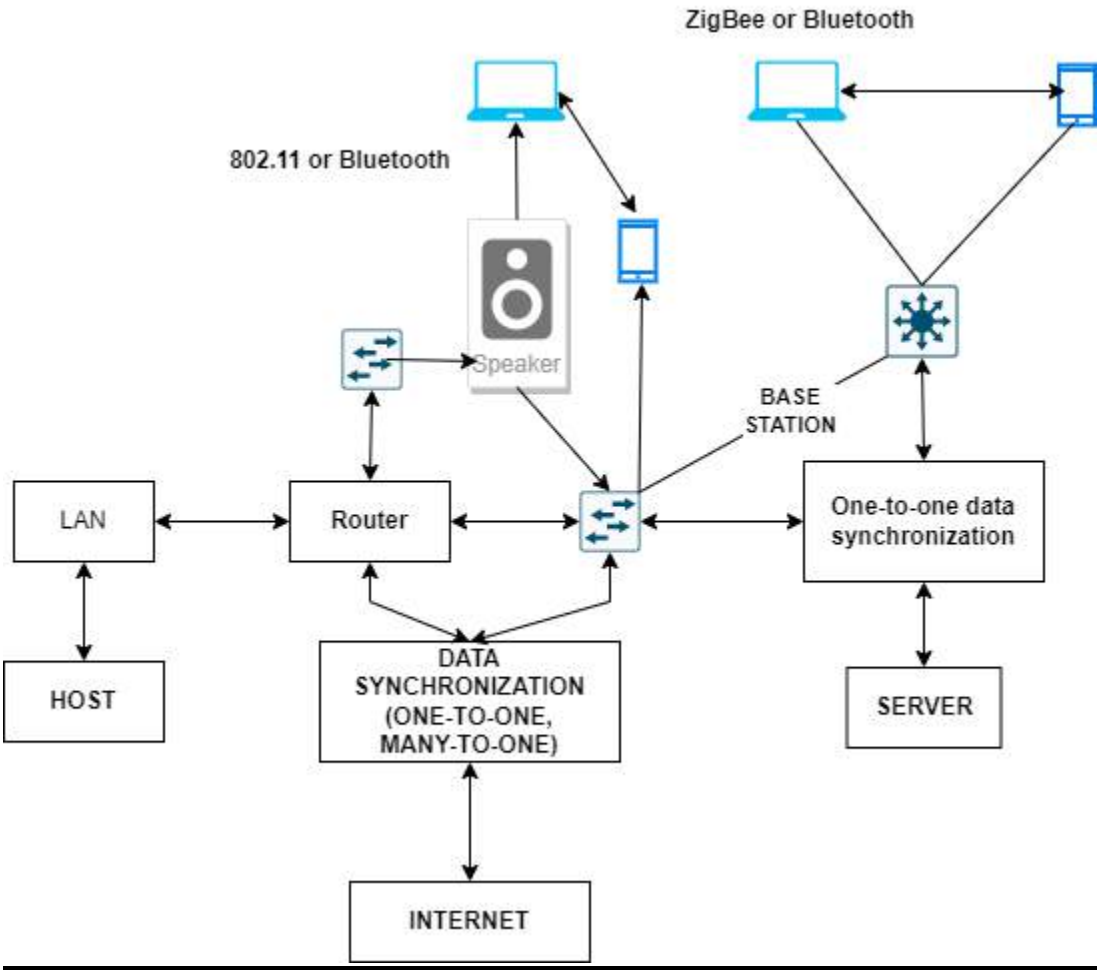


Fig 6: Data synchronization paths

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.

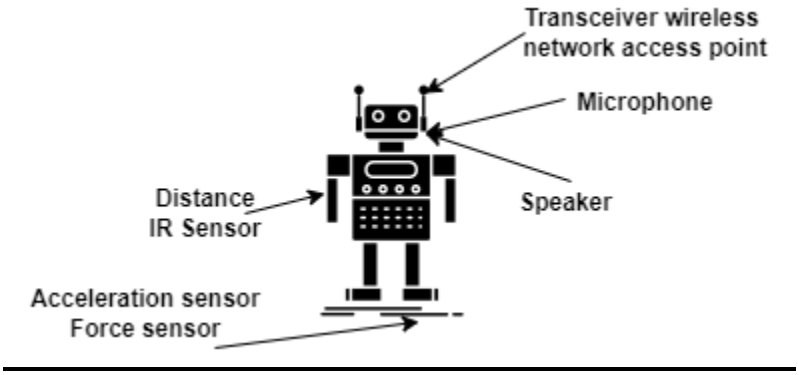

Figure 1

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.

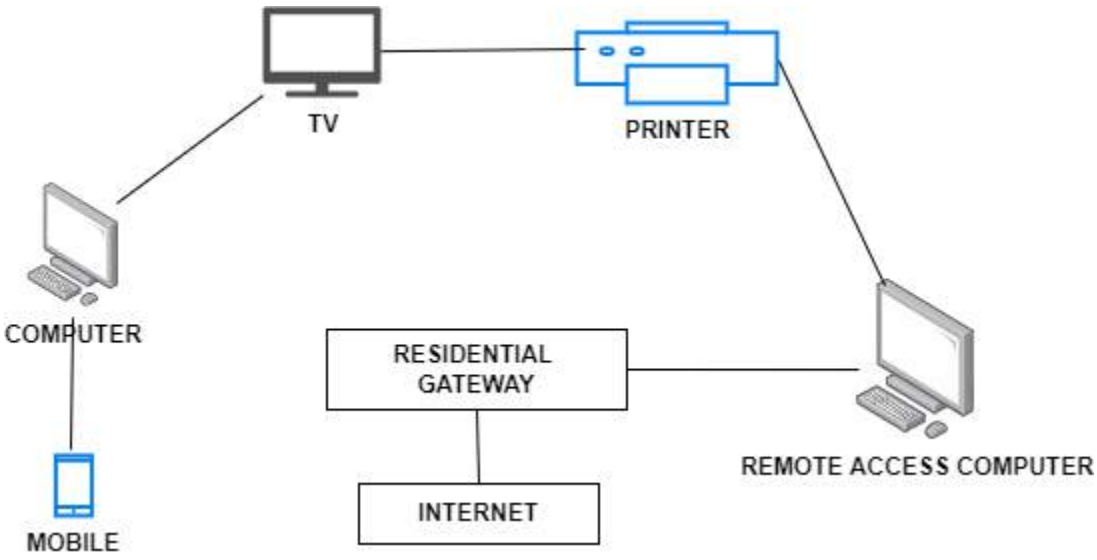

Figure 2

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.

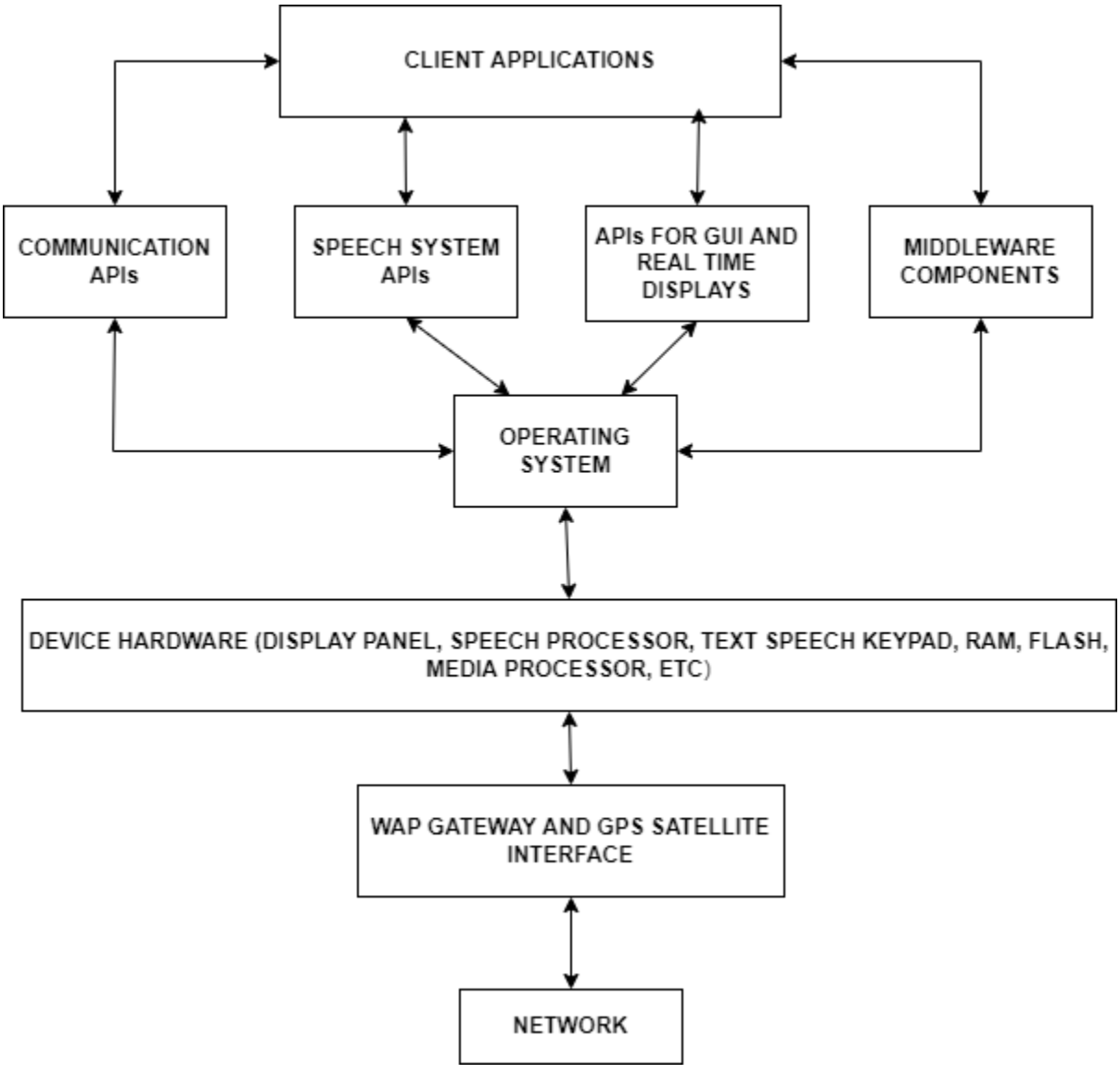

Figure 3

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 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

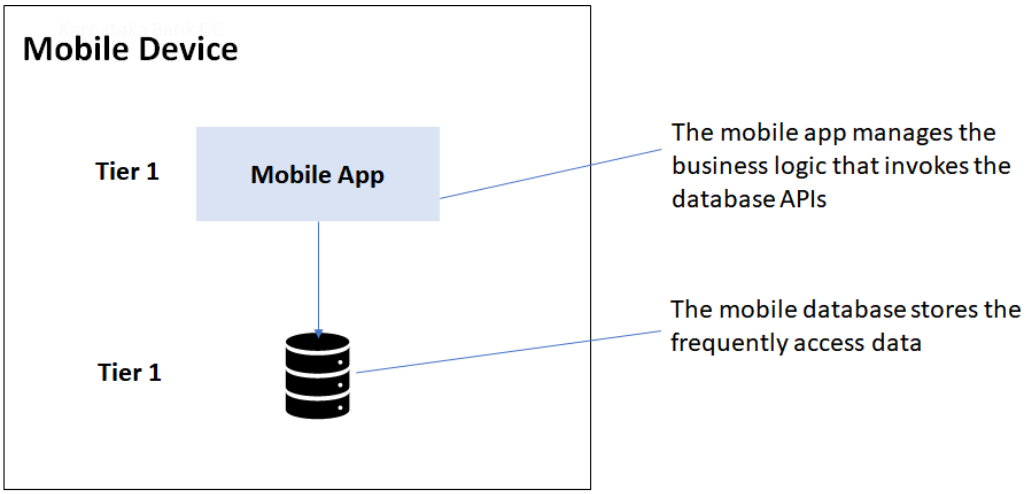

Figure 1 Single Tier Mobile database architecture

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.

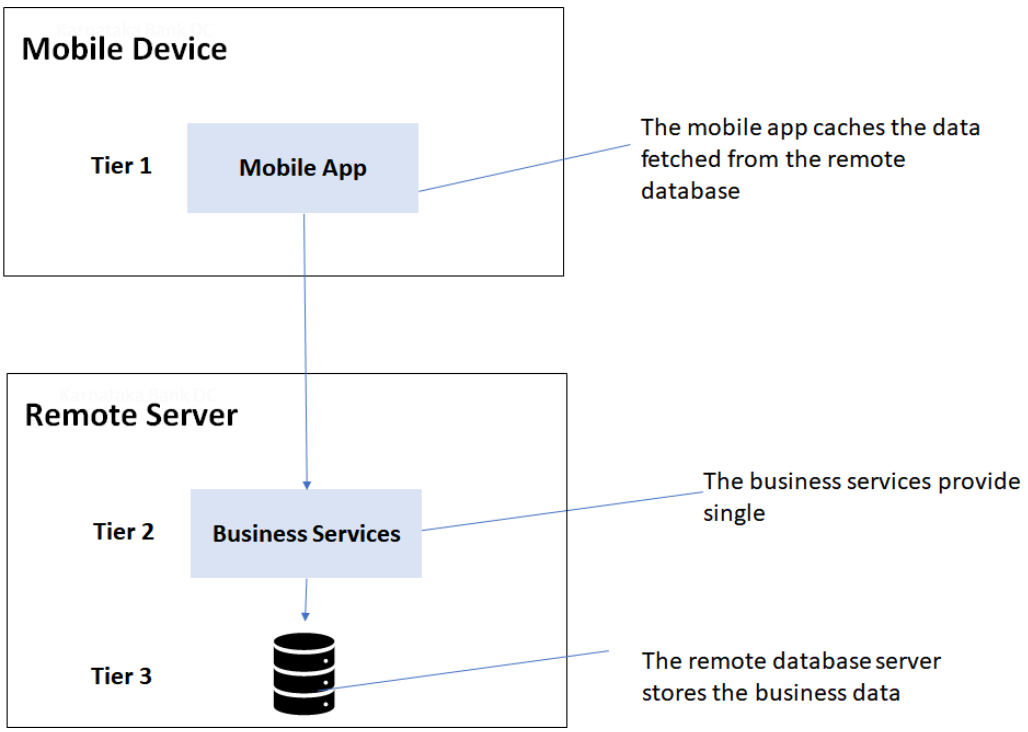

Figure 2 Multi-tier Mobile Database Architecture

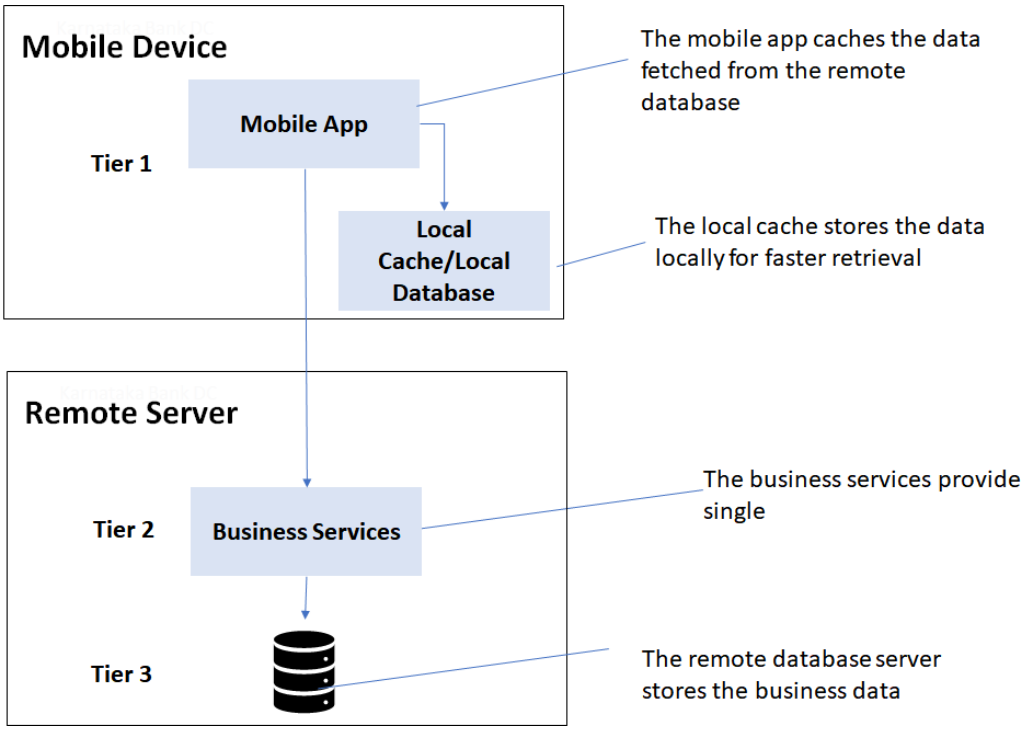

Figure 3 Multi-tier Mobile Database Architecture With Local Caching

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.

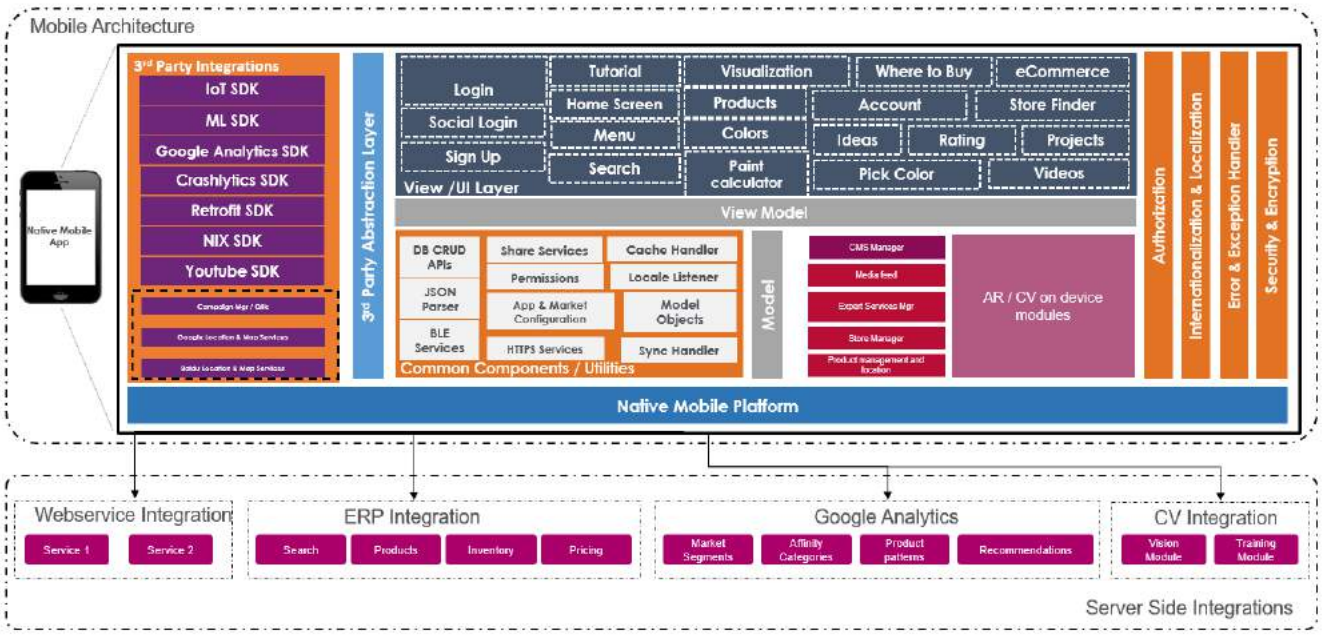

Figure 4 Multi-tier Architecture for an enterprise mobile app

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.

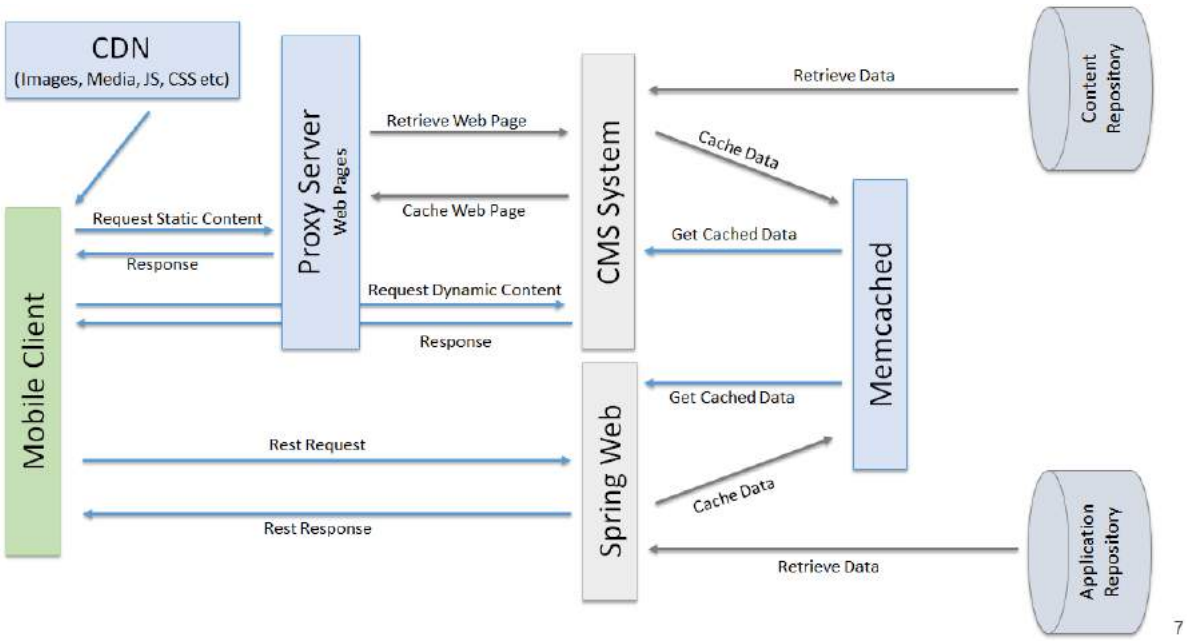

Figure 5 Pull pattern of caching

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

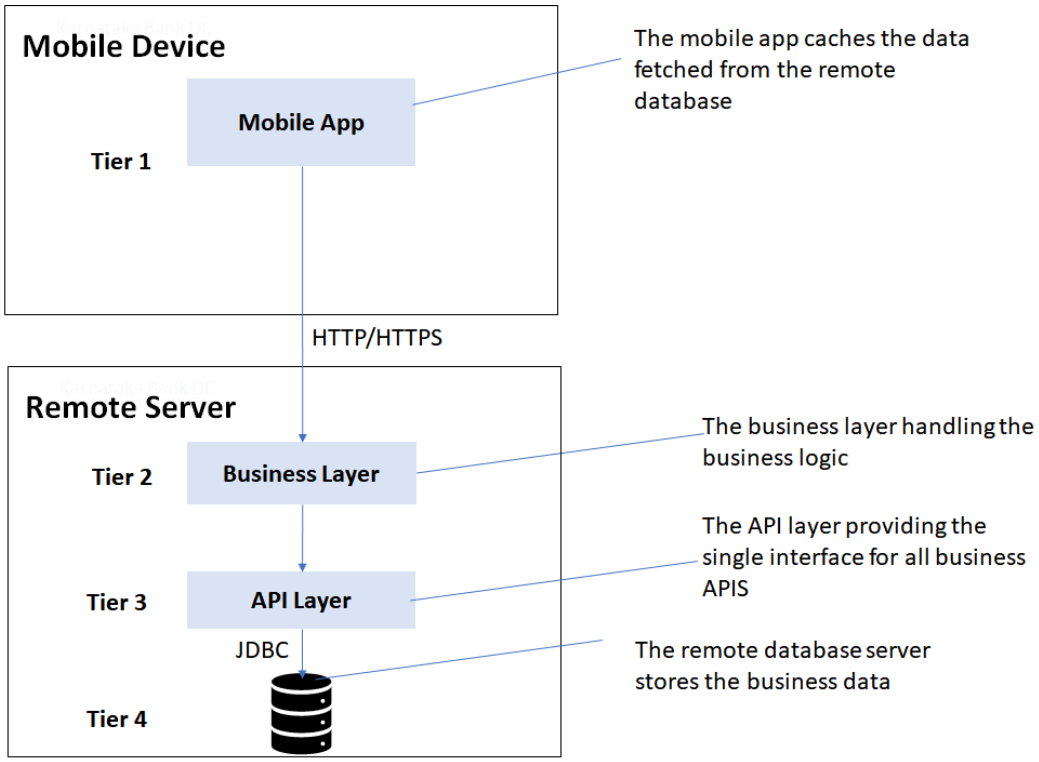

Figure 6 Four-tier mobile computing architecture

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.

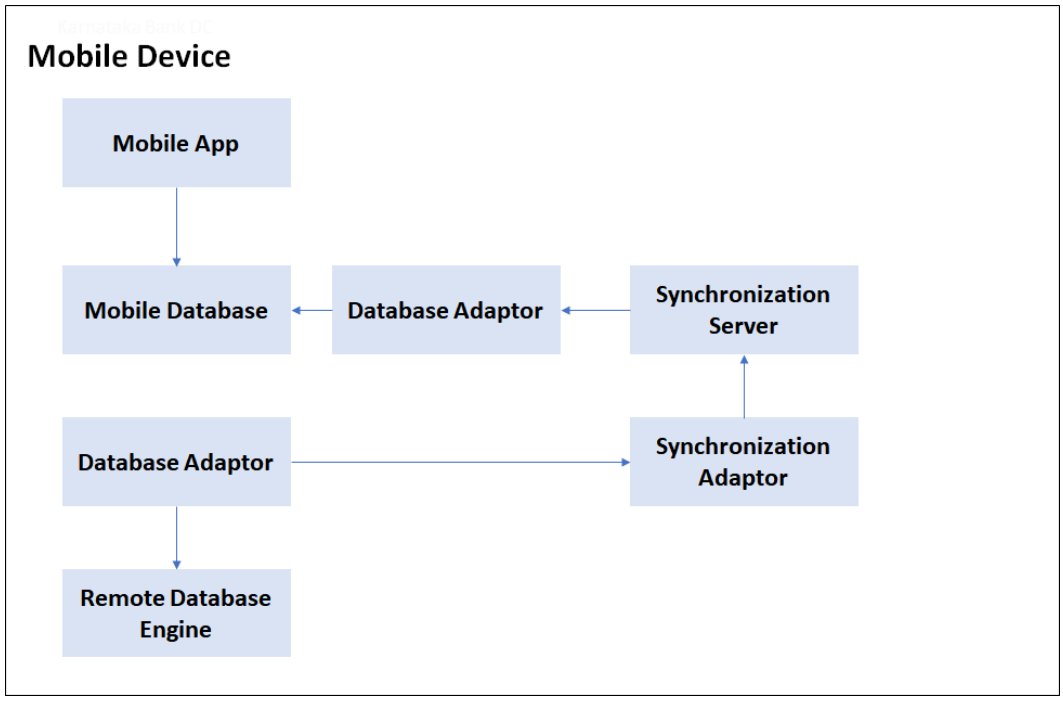

Figure 7 Adaptors at mobile device

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 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.

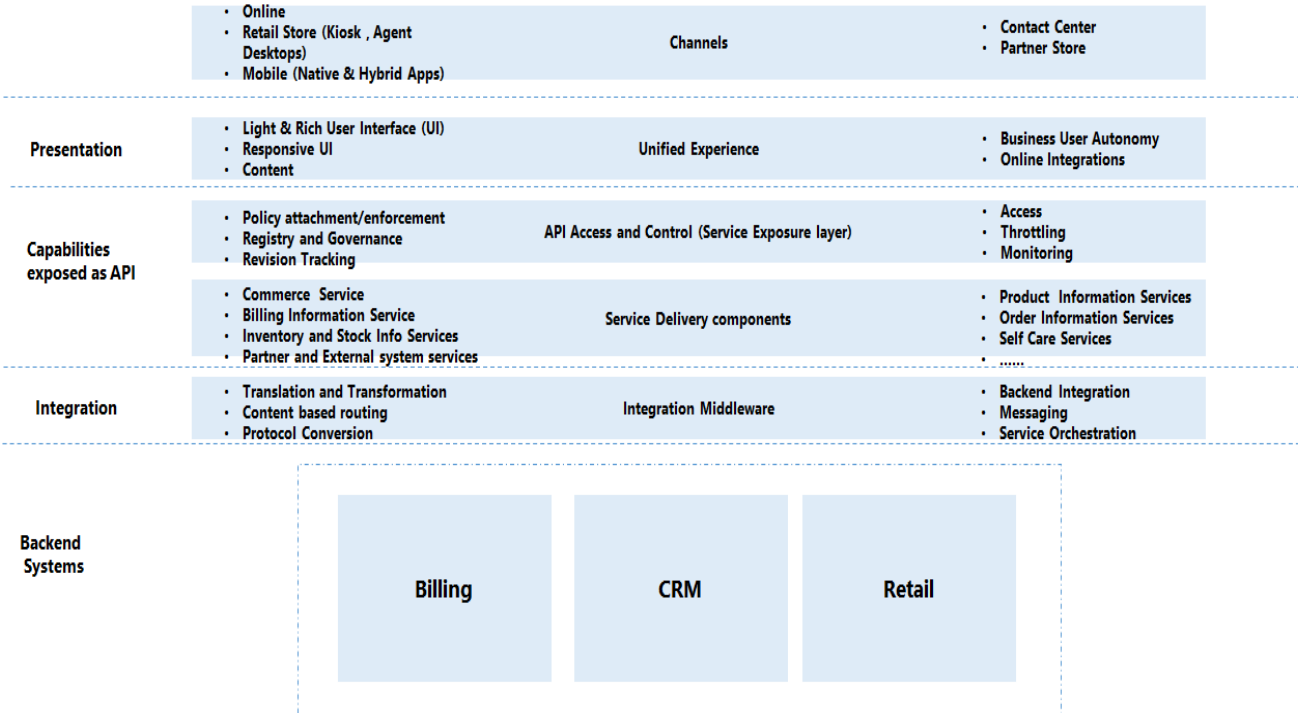

Figure 1 Layer wise Enterprise Application components

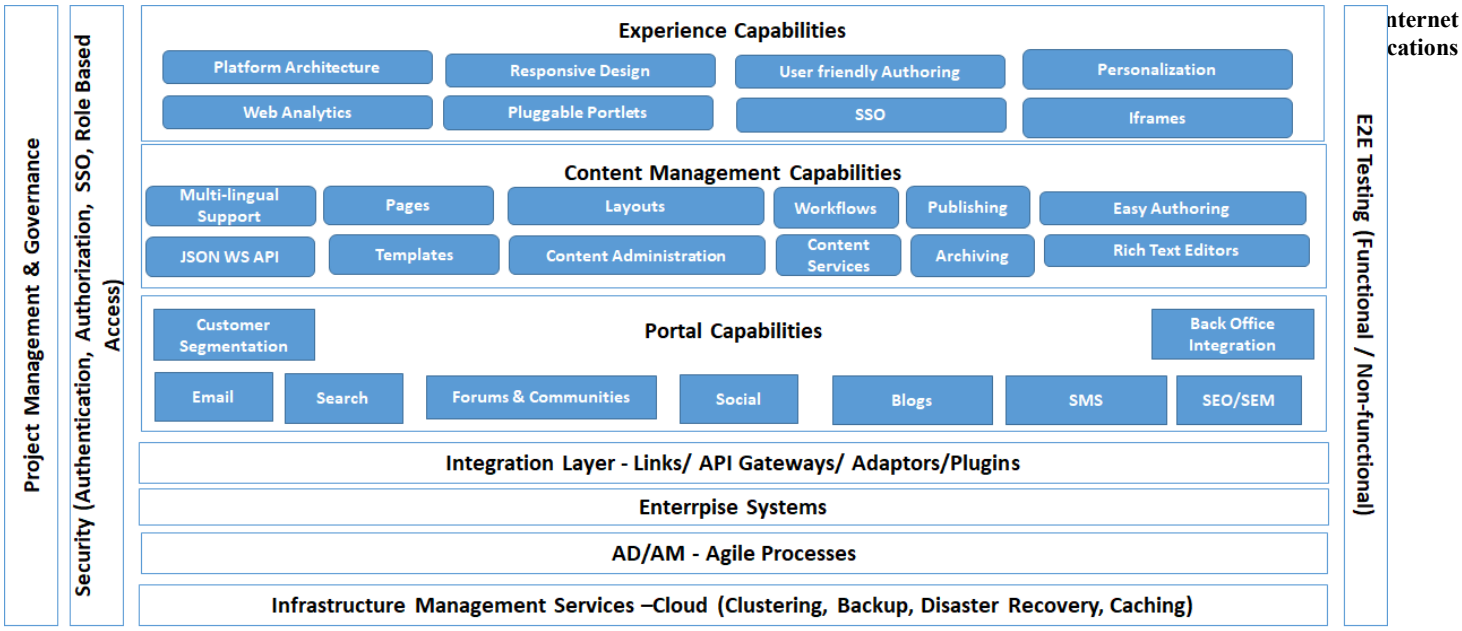

Figure 2 Content management application

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.

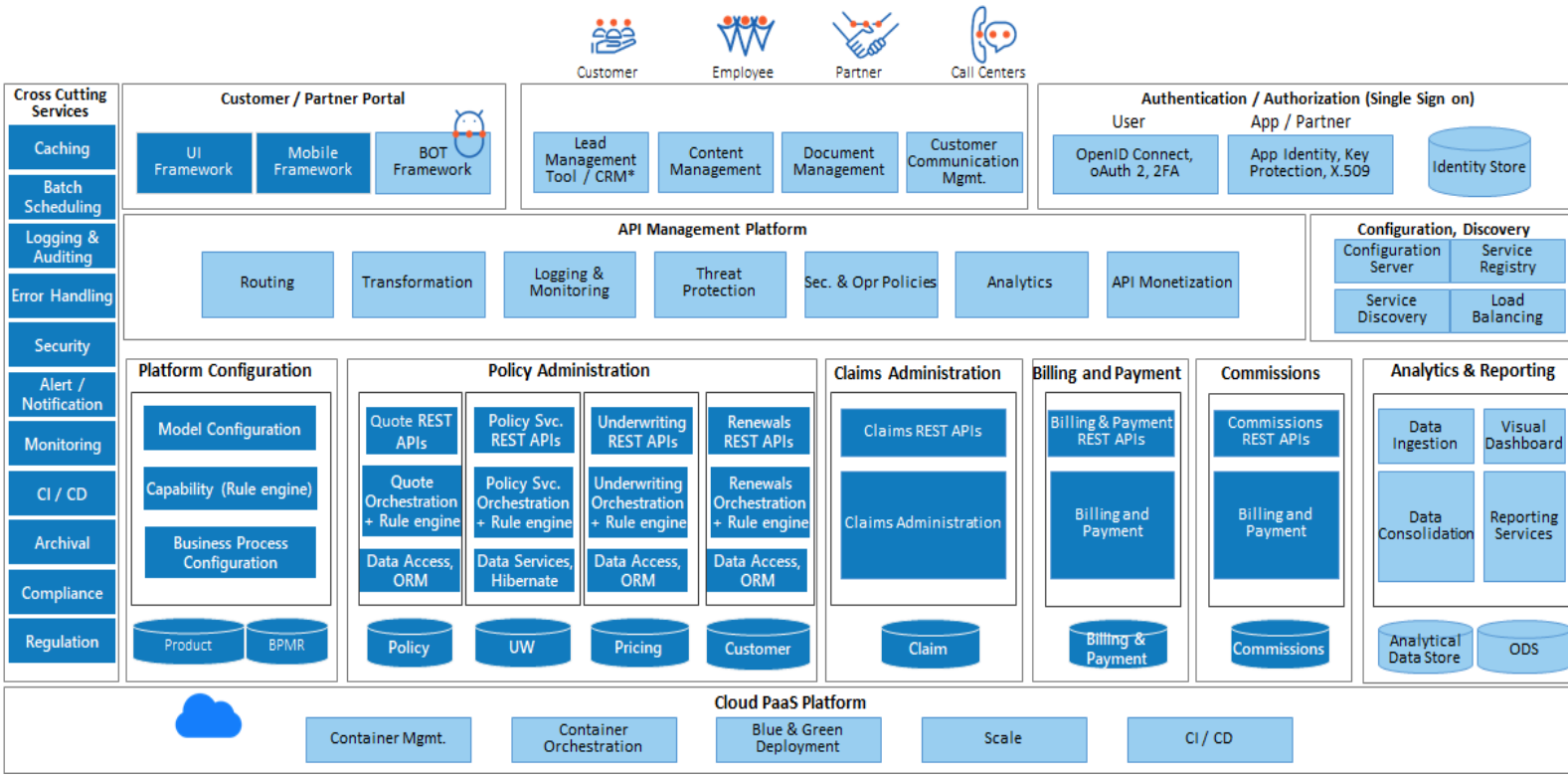

Figure 3 Layer wise components for Insurance application

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

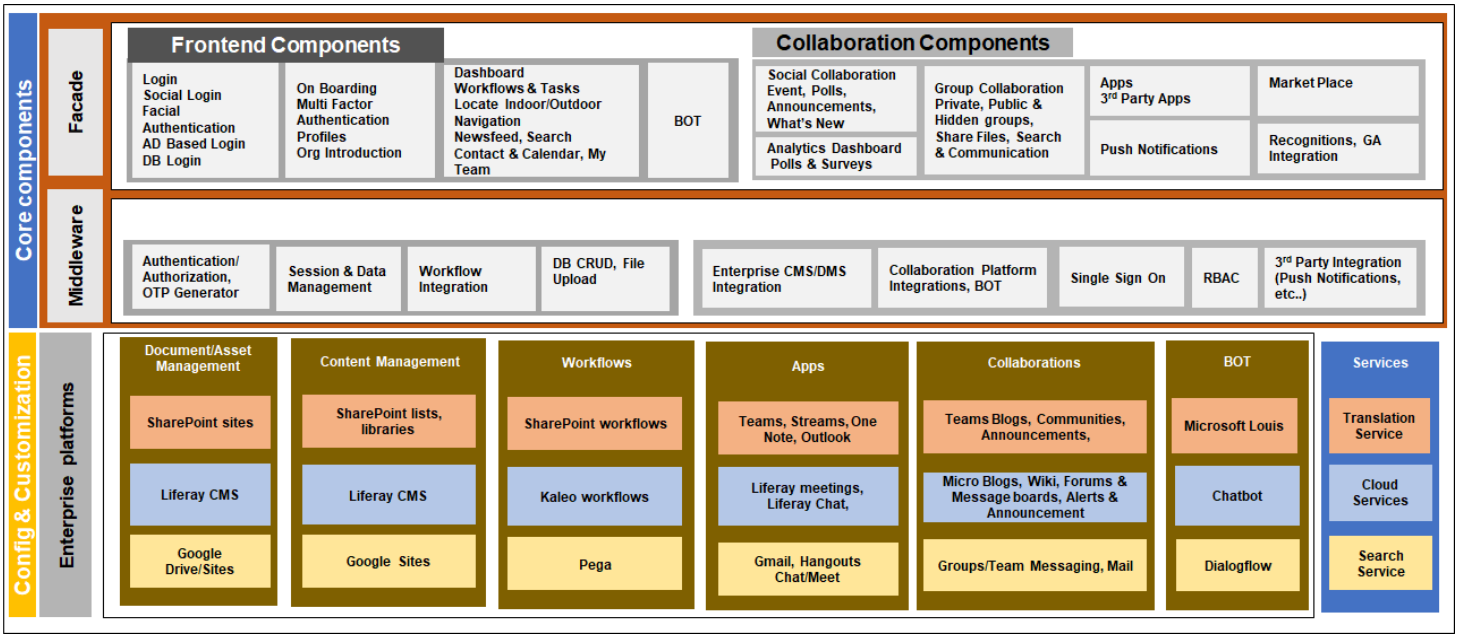

Figure 4 Enterprise Systems

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.

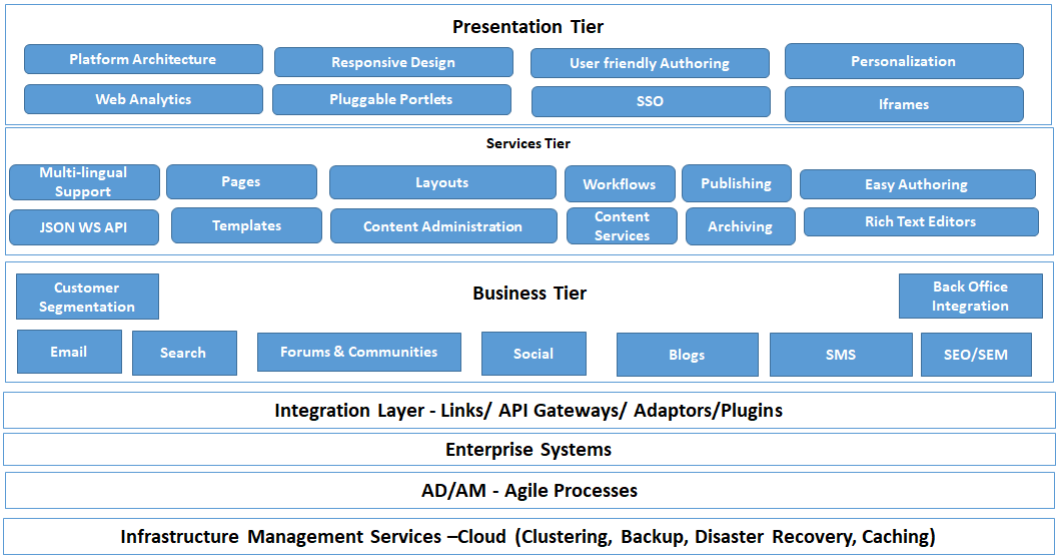

Figure 1 Sample N-Tier Architecture

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.

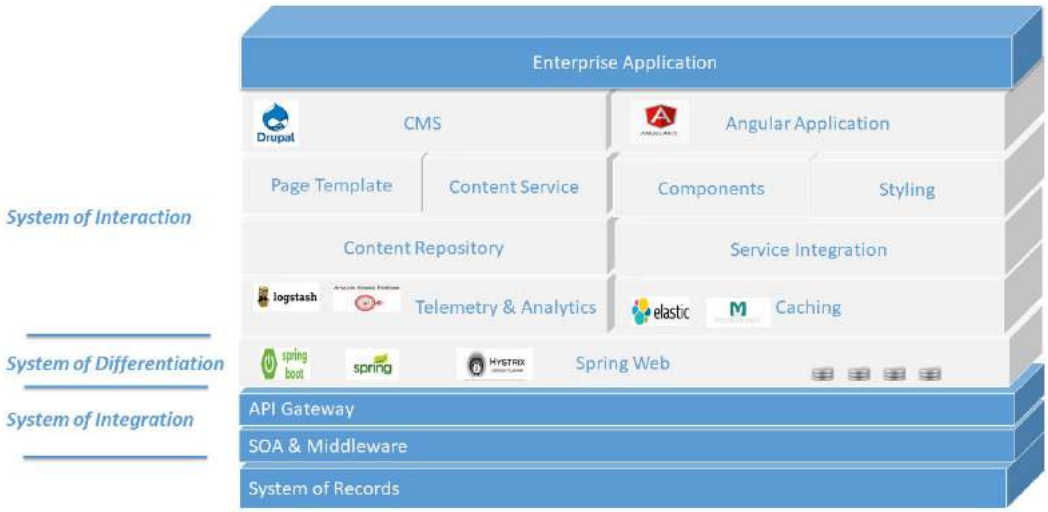

Figure 2 Systems View of the architecture

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.

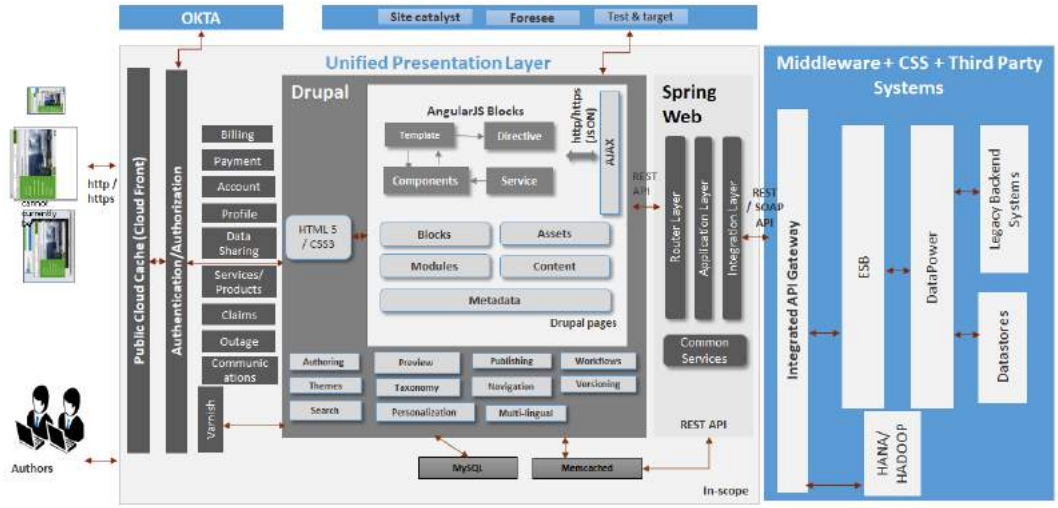

Figure 3 Request pipeline processing in enterprise application

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.

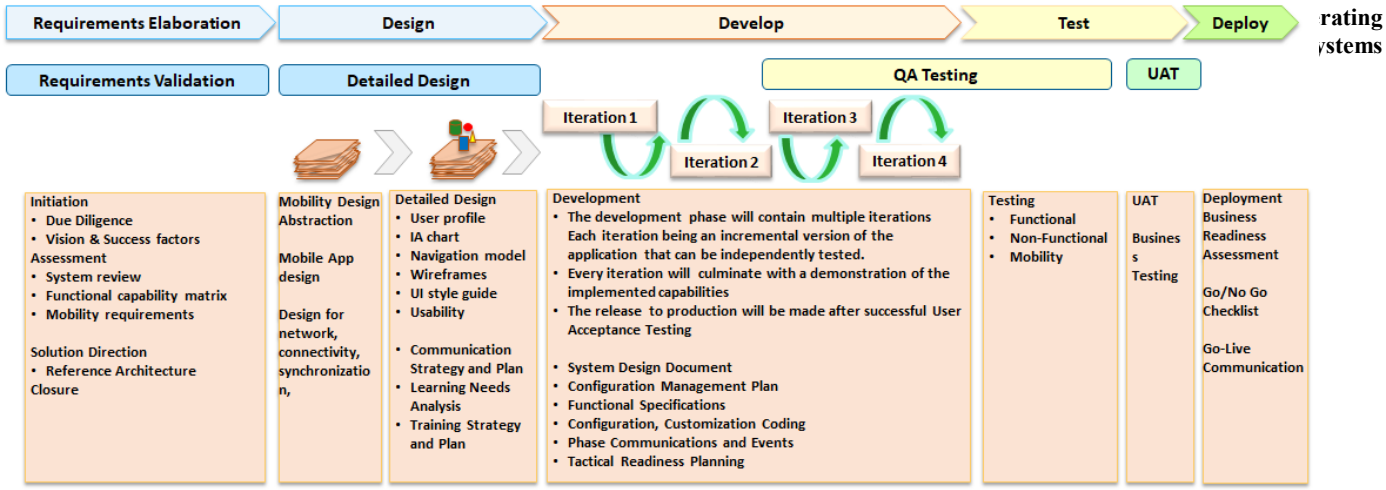

Figure 1 Phases in the development process

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.

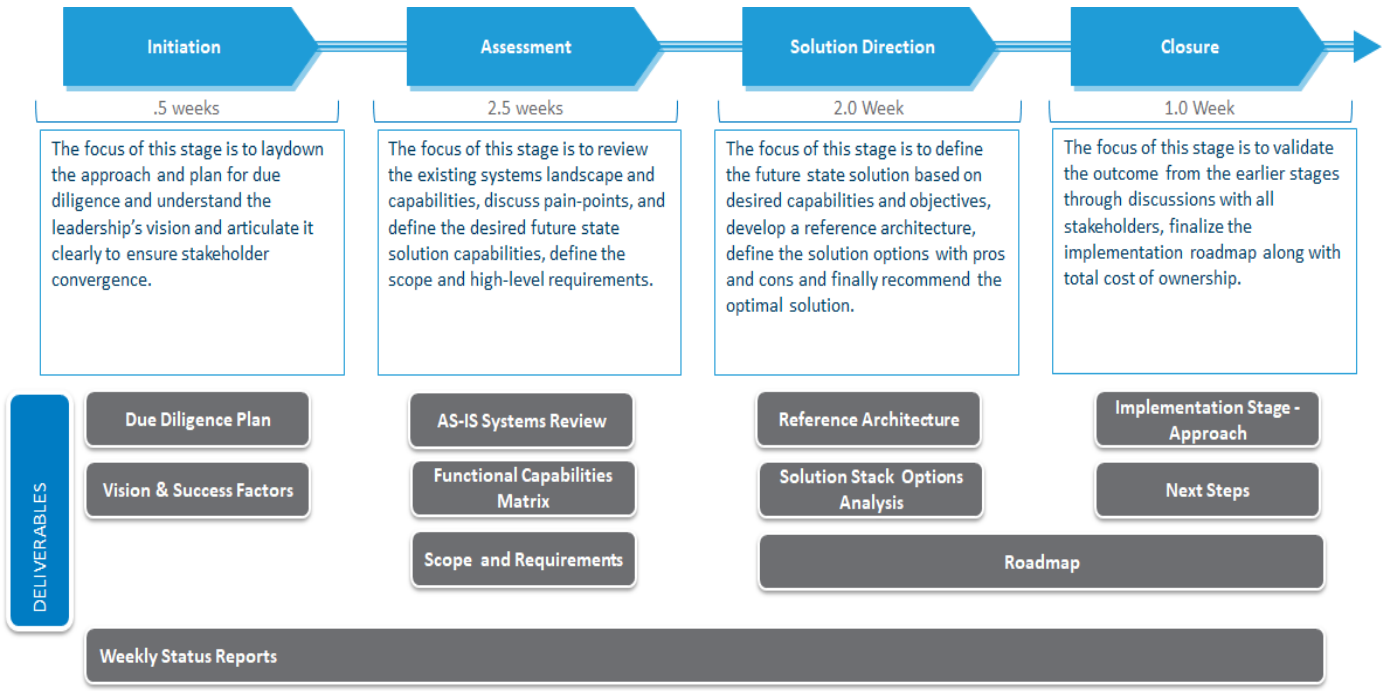

Figure 2 Requirements Elaboration Phase

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

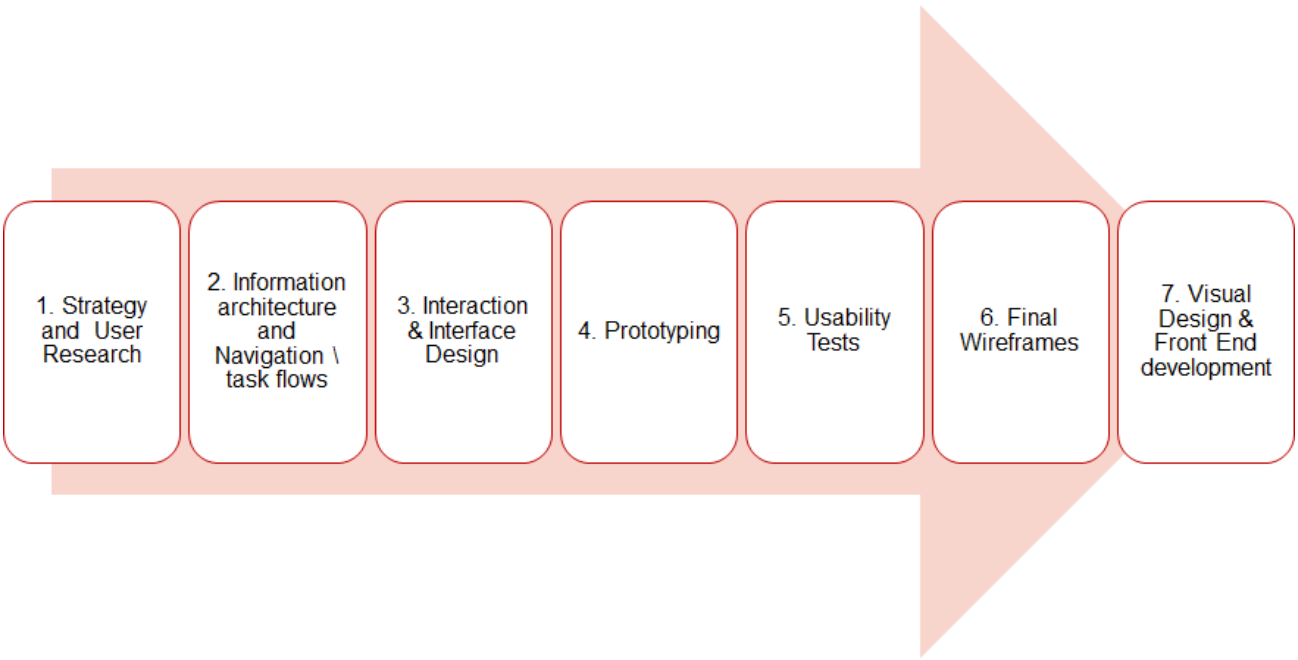

Figure 3 Visual Design Steps

The main deliverable of the user interface design is depicted in figure 4.

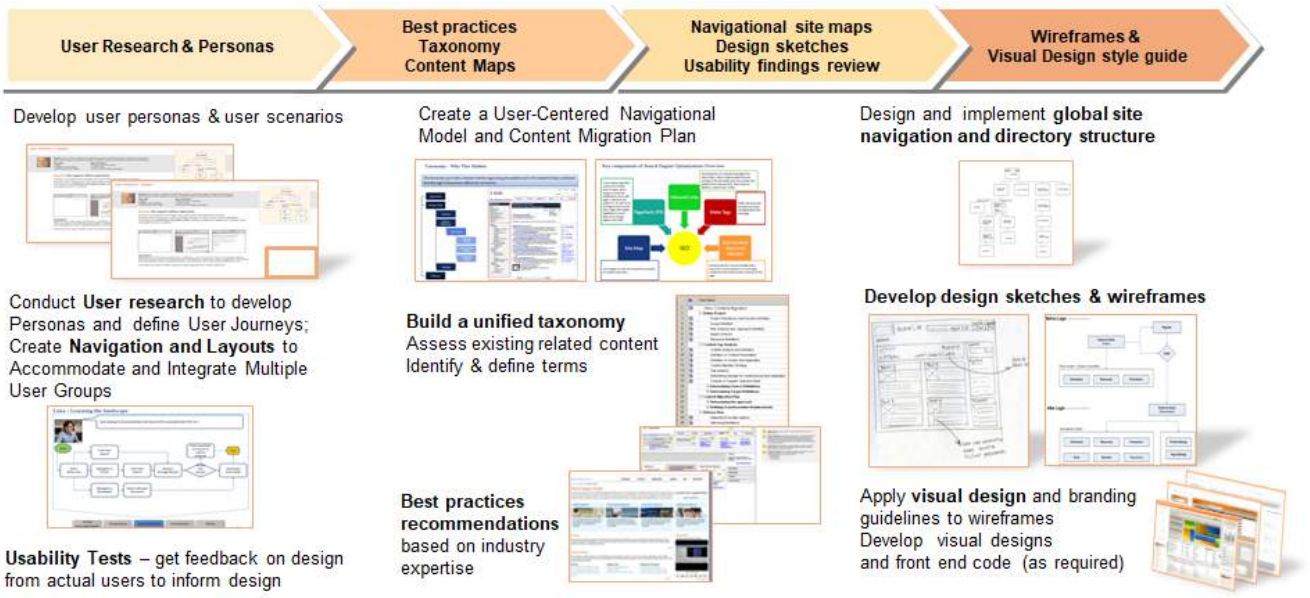

Figure 4 User interface design deliverable

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.

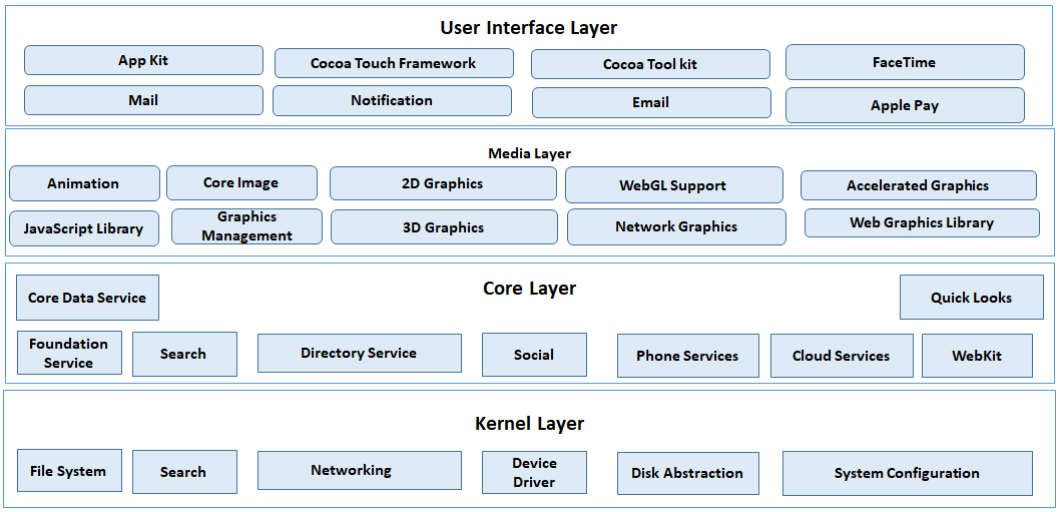

Figure 5 Apple iOS architecture

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.

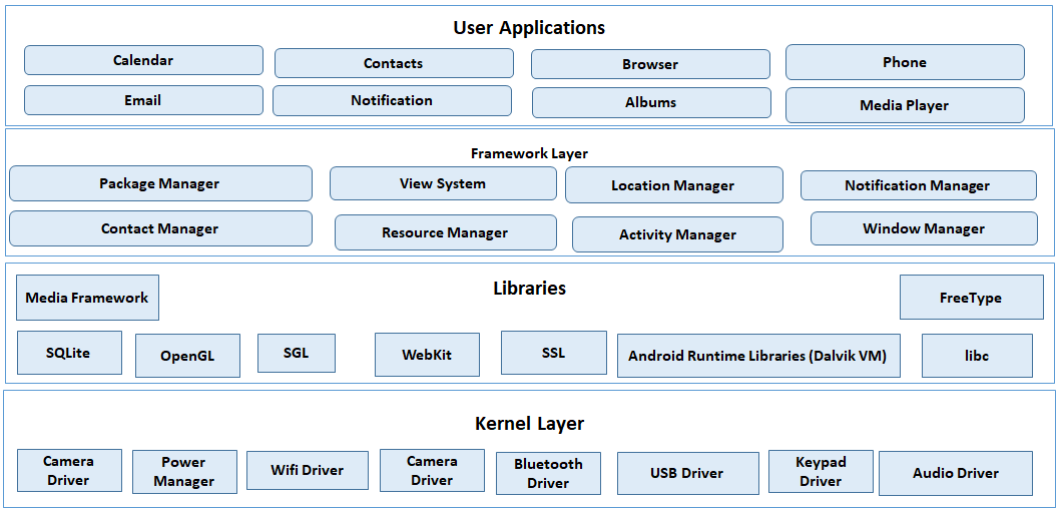

Figure 6 Android Architecture

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