

## SCORING INDICATORS

COURSE NAME : **MOBILE AND WIRELESS COMMUNICATION**

COURSE CODE : **5202**

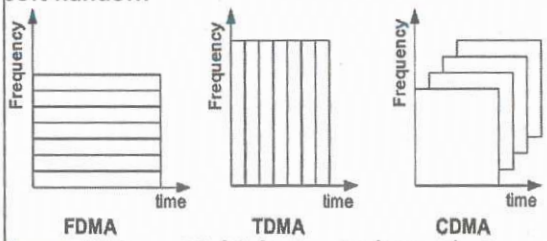
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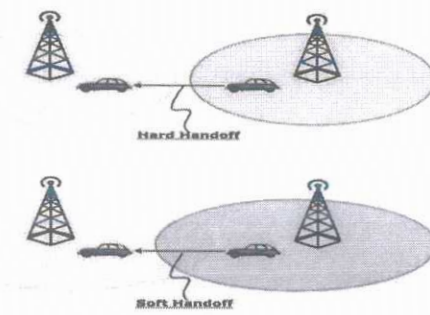
Q No	Scoring Indicators	Splitscore	Sub Total	Total score
<b>PART A</b>			1	<b>9</b>
I. 1	Hexagonal		1	9
I. 2	TRAI-Telecom Regulatory Authority of India		1	
I. 3	Air interface or Um interface		1	
I. 4	GMSK(Gaussian Minimum Shift Keying)		1	
I. 5	UMTS Terrestrial Radio Access Network		1	
I. 6	<ul style="list-style-type: none"> <li>• In laptops, notebooks and wireless PCs</li> <li>• In mobile phones and PDAs (personal digital assistant).</li> <li>• In printers.</li> <li>• In wireless headsets.</li> <li>• In wireless PANs (personal area networks) and even LANs (local area networks)</li> <li>• To transfer data files, videos, and images and MP3 or MP4.</li> <li>• In wireless peripheral devices like mouse and keyboards.</li> <li>• In data logging equipment.</li> <li>• In the short-range transmission of data from sensors devices to sensor nodes like mobile phones.</li> </ul>	Any two of these can be given mark 0.5 mark each	1	
I. 7	Ratio of spread band width to original bandwidth		1	
I. 8	LTE-Long Term Evolution		1	
I. 9	OFDMA- Orthogonal Frequency Division Multiple Access Technology		1	
<b>PART B</b>				<b>24</b>
II. 1	TDMA (Time Division Multiple Access) is a wireless communication technique. TDMA-Used when continuous transmission not required. Time slot given for each user. Full bandwidth can be allotted to a user. Handoff process simple.		3	
II. 2	Reflection, Diffraction, scattering, Multipath propagation	Any three. One mark each	3	
II. 3	<ul style="list-style-type: none"> <li>• Packet Delivery</li> <li>• Mobility management</li> <li>• LLC (Logical Link Control) management</li> <li>• Authentication</li> <li>• billing</li> </ul>	Any three. One mark each	3	

II. 4	<ul style="list-style-type: none"> <li>• CAMEL-Customized Applications for Mobile networks Enhanced Logic</li> <li>• CAMEL provides the mechanisms to support operator specific services, which are not covered by standardized GSM services.</li> <li>• Service is available when roaming to other networks also</li> <li>• Set of standards designed to work on either a GSM core network or the Universal Mobile Telecommunications System (UMTS) network.</li> <li>• The framework provides tools for operators to define additional features for standard GSM services/UMTS services.</li> </ul>	Any 3 point One mark each	3	
II. 5	<p>GSM air interface is also called Um interface Connects Mobile Station and BTS</p> <p>Consists of Physical Layer, Data Link Layer in OSI model Featured with power control, saves the battery power of MS If air distance is large, power required also higher.</p>		3	
II. 6	<p>RNC-Radio Network Controller.</p> <p>The RNC is a functional element of the UMTS RNS (Radio Network System) which controls a number of NodeBs.</p> <p>Responsibilities of the RNC include</p> <p><b>radio resource management and control,</b> <b>air interface security,</b> <b>mobility procedures and system synchronization</b></p>		3	
II. 7	<p><b>WiMAX Technology</b></p> <ul style="list-style-type: none"> <li>• <b>Definition:</b> Worldwide Interoperability for Microwave Access, a wireless broadband technology.</li> <li>• <b>Standards:</b> Based on IEEE 802.16 standards for fixed and mobile broadband.</li> <li>• <b>Range:</b> Offers coverage up to 30 miles for fixed services and several miles for mobile.</li> <li>• <b>Speed:</b> Provides high data rates, typically up to 1 Gbps in ideal conditions.</li> </ul>	Any three of this can be given one mark each	3	

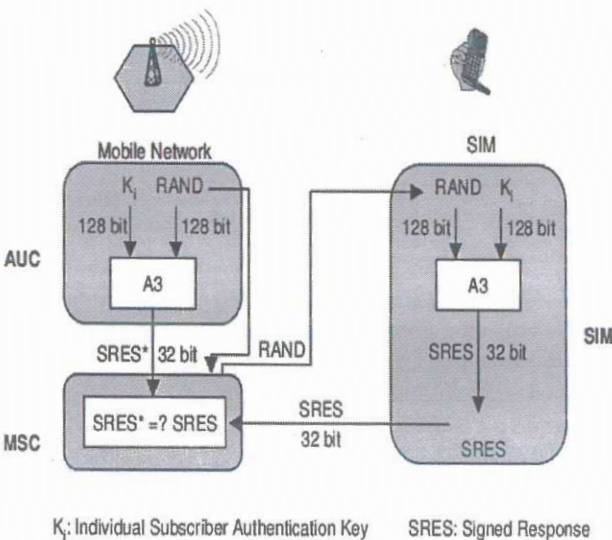
	<ul style="list-style-type: none"> <li>• <b>Frequency Bands:</b> Operates in various bands, including 2.3 GHz, 2.5 GHz, and 3.5 GHz.</li> <li>• <b>OFDM:</b> Utilizes Orthogonal Frequency Division Multiplexing for efficient spectrum use.</li> <li>• <b>Quality of Service (QoS):</b> Ensures reliable performance for different applications.</li> </ul> <p><b>Applications:</b> Suitable for Internet access, VoIP, and multimedia streaming</p>			
II. 8	<ol style="list-style-type: none"> <li>1. <b>Higher Data Rates:</b> Data rates upto 20Gbps</li> <li>2. <b>Low Latency:</b> ultra-low latency, critical for applications like real-time gaming, autonomous vehicles, and remote surgery.</li> <li>3. <b>Massive Device Connectivity:</b></li> <li>4. <b>Enhanced Mobile Broadband (eMBB)</b></li> <li>5. <b>Ultra-Reliable Low Latency Communications</b></li> <li>6. <b>Network Slicing:</b></li> <li>7. <b>Beamforming and MIMO:</b></li> <li>8. <b>Millimeter Wave (mm Wave):.</b></li> <li>9. <b>Dynamic Spectrum Sharing (DSS):</b></li> <li>10. <b>Network Function Virtualization (NFV) and Software-Defined Networking (SDN)</b></li> <li>11. <b>Security Enhancements:</b></li> <li>12. <b>Global Standardization:</b></li> </ol>	Any three of this can be given one mark each	3	
II.9	<p>Release 8 – LTE Introduced</p> <p>Release 10 – LTE Advanced</p> <p>Release 14 – The start of 5G standardization(Release 15 also )</p>		3	
II.10	<ul style="list-style-type: none"> <li>• Voice over LTE (VoLTE) is a technology that enables voice calls to be made over the Long-Term Evolution (LTE) network, which is the standard for high-speed wireless communication commonly referred to as 4G.</li> <li>• VoLTE represents a significant advancement in telecommunications and has several advantages over traditional circuit-switched voice calls</li> <li>• VoLTE is based on the IP Multimedia Subsystem (IMS) architectural framework.</li> <li>• Superior voice quality, faster call setup,</li> </ul> <p>Can use voice and data service simultaneously</p>		3	
	<b>PART C</b>			<b>42</b>
III.	When distance between MS(Mobile Station) and BTS changes		7	

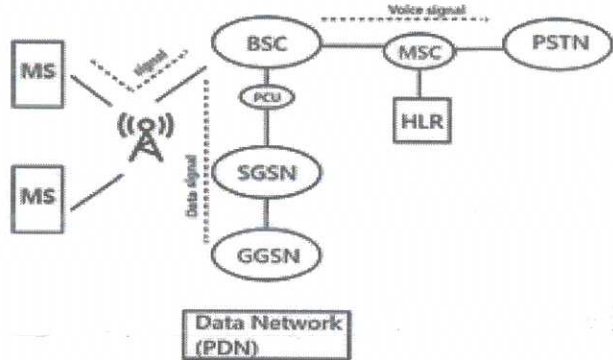
	<p>the power output of their signals varies.</p> <p>For Large distance, higher power required.</p> <p>When distance is less, power level has to reduced.</p> <p>This saves the battery life of MS</p> <p>The BSS controls the transmit power of both the MS and the BTS.</p> <p>The received MS power is monitored by the BSS and the receive BTS power is monitored by the MS and then reported to the BSS.</p> <p>Using these measurements the power of both MS and BTS can be adjusted accordingly</p> <p>Power control in GSM (Global System for Mobile Communications) is essential for optimizing network performance and ensuring efficient use of radio resources. It helps maintain call quality and extends battery life in mobile devices. The system employs two types of power control: <b>open-loop</b> and <b>closed-loop</b>.</p> <ol style="list-style-type: none"> <li>1. <b>Open-Loop Power Control:</b> This method adjusts the mobile station's transmit power based on the signal strength measured by the base station when a call is initiated. The base station estimates the necessary power level without direct feedback from the mobile device.</li> <li>2. <b>Closed-Loop Power Control:</b> Once the call is established, the base station continuously monitors the received signal quality. It sends power control commands to the mobile device, instructing it to increase or decrease its transmission power in small increments, typically by 1 dB.</li> </ol>			
<p>IV.</p>	<p>Multiple access techniques used to access channel in a communication system.</p> <p><b>FDMA</b>-allots a different sub-band of frequency to each different user to access the network. In FDMA a channel is not in use, the channel is left idle instead of allotting to the other users. Continuous transmission possible.</p> <p><b>TDMA</b>-Used when continuous transmission not required. Time slot given for each user. Full bandwidth can be allotted to a user. Handoff process simple.</p> <p><b>CDMA- Code Division Multiple Access (CDMA)</b>-Code division multiple access technique is an example of multiple access where several transmitters use a single channel. Full spectrum can be</p>	<p>Explanation 4 Figure-3 If sufficient information given without</p>	<p>7</p>	

	<p>used by a single user. Continuous transmission possible. Provides soft handoff.</p>  <p><b>FDMA</b>      <b>TDMA</b>      <b>CDMA</b></p> <p><b>Space Division Multiple Access (SDMA)</b>- Space division multiple access or spatial division multiple access is a technique which is MIMO (multiple-input multiple-output) architecture and used mostly in wireless and satellite communication</p> <p><b>Spread Spectrum Multiple Access(SSMA)</b>- Spread spectrum multiple access (SSMA) uses signals which have a transmission bandwidth whose magnitude is greater than the minimum required RF bandwidth. Two type Spread spectrum techniques- <b>FHSS</b>, <b>DSSS</b></p>	<p>figure full mark can be given</p>		
<p>V.</p>	<p><b>HANDOFF</b></p> <p>In cellular communications, the handoff is the process of transferring an active call or data session from one cell in a cellular network or from one channel to another.</p> <p>In satellite communications, it is the process of transferring control from one earth station to another.</p> <p>Handoff is necessary for preventing loss of interruption of service to a caller or a data session user. Handoff is also called handover</p> <p>Situations triggering Handoff</p> <ul style="list-style-type: none"> <li>• If a subscriber who is in a call or a data session moves out of coverage of one cell and enters coverage area of another cell, a handoff is triggered.</li> <li>• Each cell has a pre-defined capacity, i.e. it can handle only a specific number of subscribers. If the number of users using a particular cell reaches its maximum capacity, then a handoff occurs</li> <li>• Cells are often sub-divided into microcells. A handoff may occur when there is a transfer from the large cell to the smaller cell and vice versa.</li> <li>• Handoffs may also occur when there is an interference of calls using the same frequency for communication.</li> </ul> <p><b>TYPES OF HANDOFF</b></p> <ul style="list-style-type: none"> <li>• <b>Hard Handoff</b> – In a hard handoff, an actual break in the</li> </ul>	<p>Explanation for Handoff and types of Handoff(Hard, Soft)- 5 marks Figure 2 marks</p>	<p>7</p>	

	<p>connection occurs while switching from one cell to another. The radio links from the mobile station to the existing cell is broken before establishing a link with the next cell. It is generally an inter-frequency handoff. It is a “break before make” policy.</p> <ul style="list-style-type: none"> <li>• <b>Soft Handoff</b> – In soft handoff, at least one of the links is kept when radio links are added and removed to the mobile station. This ensures that during the handoff, no break occurs. This is generally adopted in co-located sites. It is a “make before break” policy.</li> <li>• <b>Mobile Assisted Handoff (MAHO)</b> is a technique in which the mobile devices assist the Base Station Controller (BSC) to transfer a call to another BSC. It is used in GSM cellular networks.</li> </ul> 			
<p>VI.</p>	<p><b>1. Call Initiation</b></p> <ul style="list-style-type: none"> <li>• <b>User Action:</b> The caller dials a number on their mobile device.</li> <li>• <b>Signal Generation:</b> The mobile device generates a signaling message indicating a call request.</li> </ul> <p><b>2. Accessing the Network</b></p> <ul style="list-style-type: none"> <li>• <b>Cell Selection:</b> The mobile device connects to the nearest cell tower (base station) based on signal strength.</li> <li>• <b>Channel Allocation:</b> The network allocates a radio channel for the call.</li> </ul> <p><b>3. Call Setup Procedure</b></p> <ul style="list-style-type: none"> <li>• <b>Signaling to the Network:</b> The mobile device sends a request to the base station, which forwards it to the Mobile Switching Center (MSC).</li> <li>• <b>Authentication:</b> The MSC verifies the caller's identity, checking if the mobile number is valid and if the user has</li> </ul>		<p>7</p>	

	<p>sufficient balance or is authorized to make the call.</p> <p><b>4. Routing the Call</b></p> <ul style="list-style-type: none"> <li>• <b>Destination Lookup:</b> The MSC looks up the recipient's mobile number in its database to find the corresponding MSC for the recipient.</li> <li>• <b>Signal Forwarding:</b> The call setup request is routed through various network elements, potentially involving multiple MSCs.</li> </ul> <p><b>5. Establishing the Connection</b></p> <ul style="list-style-type: none"> <li>• <b>Ring the Recipient:</b> Once the recipient MSC is identified, it forwards the call request to the recipient's mobile device, which may cause it to ring.</li> <li>• <b>Recipient Response:</b> If the recipient answers, a two-way connection is established.</li> </ul> <p><b>6. Call Connection</b></p> <ul style="list-style-type: none"> <li>• <b>Audio Channel Establishment:</b> A dedicated channel is set up for voice transmission between the two parties. This can be a circuit-switched connection in traditional systems or a packet-switched connection in VoIP.</li> </ul> <p><b>7. Call in Progress</b></p> <ul style="list-style-type: none"> <li>• <b>Voice Transmission:</b> Both parties can communicate through the established channel. Their voices are converted to digital signals and transmitted over the airwaves.</li> </ul> <p><b>8. Call Termination</b></p> <ul style="list-style-type: none"> <li>• <b>Ending the Call:</b> When either party hangs up, a disconnect signal is sent.</li> <li>• <b>Resource Release:</b> The network releases the resources (channels, signaling) that were allocated for the call.</li> </ul> <p><b>9. Post-Call Handling</b></p> <p><b>Billing and Logging:</b> The call details are logged for billing and record-keeping purposes. Call duration, time, and other metrics may be recorded.</p>		
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<p>VII.</p>	<p>Authentication process in GSM is to authenticate a user in the network.</p> <p>Each user has got a 128 Bit secret Key <math>K_i</math>. RAND is 128 bit Random number is send to Mobile station. Using A3 algorithm a 32 Bit Signed Response (SRES) generated.</p> <p>Authentication Center also having the same <math>K_i</math> and RAND. There also SRES generated. In MSC both SRES compared. If both of them are equal Authentication is successful.</p>  <p><math>K_i</math>: Individual Subscriber Authentication Key    SRES: Signed Response</p>	<p>Drawing diagram -4 Explanation 3 marks</p>	<p>7</p>	
<p>VIII.</p>	<p><u>GPRS stands for General Packet Radio Service.</u></p> <ul style="list-style-type: none"> <li>• It is the modified version of GSM architecture. GPRS is a packet-oriented mobile data mechanism, that can carry data packets as well.</li> <li>• In GSM architecture, only voice signals can be transported, so being an enhanced version GPRS is able to transmit voice as well as data packets.</li> <li>• It uses the same physical radio channel as GSM does, the only difference is it has a new logic defined for the radio channel</li> </ul> <p>ARCHITECTURE</p> <p>GPRS tries to make maximum use of the existing physical structure of GSM. It has introduced a new entity named GPRS support nodes(GSN) whose responsibility is to route and deliver a data packet.</p>	<p>Blockdiagram -4 explanation-3</p>	<p>7</p>	

	<p>GSN is of two types:</p> <ul style="list-style-type: none"> <li>• Serving GPRS Support Node (SGSN)</li> <li>• Gateway GPRS Support Node (GGSN)</li> </ul>  <p>The diagram illustrates the GPRS network architecture. On the left, two Mobile Stations (MS) are shown. A dashed line labeled 'Signal' connects them to a Base Station Controller (BSC). Below the BSC is a Packet Control Unit (PCU). A dashed line labeled 'Data signal' connects the PCU to the Serving GPRS Support Node (SGSN). Below the SGSN is the Gateway GPRS Support Node (GGSN). A dashed line labeled 'Voice signal' connects the BSC to a Mobile Switching Center (MSC). Below the MSC is the Home Location Register (HLR). A dashed line connects the MSC to the Public Switched Telephone Network (PSTN). At the bottom, a box labeled 'Data Network (PDN)' is connected to the GGSN.</p> <p>MS-Mobile station  <b>Base Station controller (BSC)</b>          In GSM architecture there is one component called BSC. But in GPRS there is one component is added to BSC called PCU.          PCU stands for Packet Control Unit.          If the signal comes to BSC and that signal contains data, then PCU routes to the SGSN. The interface is used between BSC and PCU is the FRI interface.          After the signal comes to SGSN, it delivers the data packet to the GGSN. GGSN routes the data packet to the data network (PDN- Public Data Network).</p>			
<p>IX.</p>	<p>UMTS uses <b>wideband code-division multiple access (W-CDMA) radio access technology</b> to offer greater spectral efficiency and bandwidth to mobile network operators.          WCDMA uses spread spectrum technology, which allows multiple users to share bandwidth with no interference.          It employs a <b>5 MHz</b> channel bandwidth(Normal CDMA only 1.25MHz)          Using this bandwidth it has the capacity to carry over 100 simultaneous voice calls, or it is able to carry data at speeds up to 2 Mbps in its original format.          WCDMA provides following data speeds</p> <ul style="list-style-type: none"> <li>- Stationary- 2 Mbps</li> <li>- Slow moving- 384 Kbps</li> <li>- Fast moving- 128 Kbps.</li> </ul> <p>WCDMA is considered to be more efficient than its second-</p>	<p>Explaining basic concepts-4 marks          Figure-3 marks</p>	<p>7</p>	

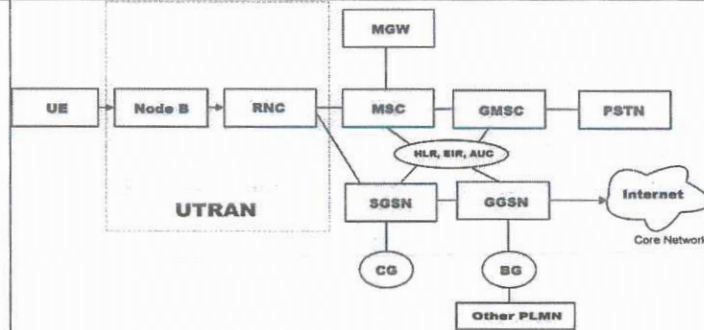
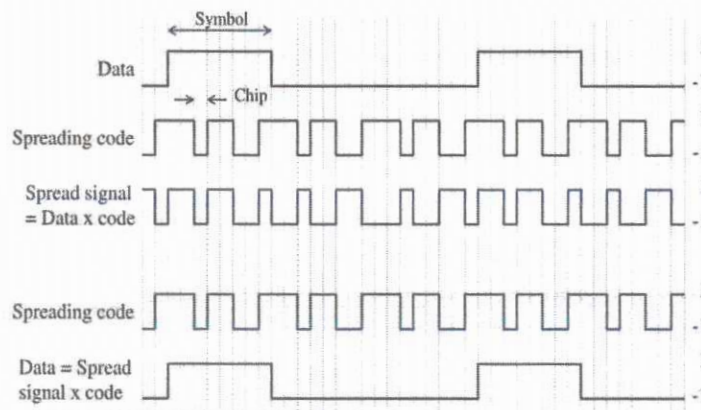
generation predecessors, as well as more secure.

Because it provides built-in encryption and relies on spread spectrum technology, WCDMA signals are much more difficult to detect. As a result, WCDMA provides more privacy for users

To spread the signal OVVSF(Orthogonal variable spreading factor codes) Codes are used.

Data signal multiplied with a code at the transmitter. So the signal get spread. Using same code multiplied at the receiver. So original data retrieved.

### Spreading/Despreading



UE: User Equipment  
 RNC: Radio Network Controller  
 SGSN: Serving GPRS Support Node  
 CG: Charging Gateway  
 BG: Border Gateway

MSC: Mobile Switching Center  
 MGW: Media Gateway  
 GMSC: Gateway MSC  
 PSTN: Public Switched Telephone Network  
 HLR: Home Location Register  
 EIR: Equipment Identity Register  
 AUC: Authentication Center

Fig: UMTS Architecture

X.

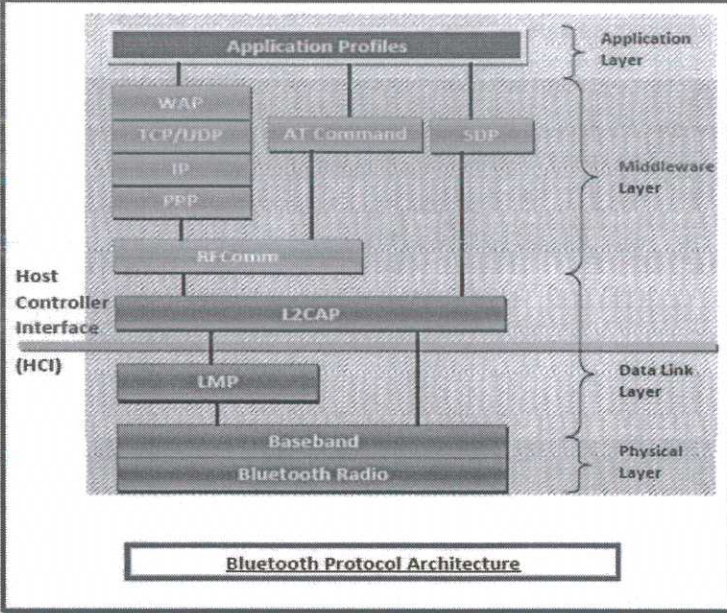
UE- user equipment( SIM+Handset) connected to NodeB. BTS in GSM replaced by NodeB in UMTS.

RNC-Radio Network Controller- Control several NodeBs and allocate radio resources. RNC-Radio Network Controller.

The RNC is a functional element of the UMTS RNS (Radio Network System) which controls a number of Node Bs. Responsibilities of the RNC include

Block diagram-4  
 Explanation-3

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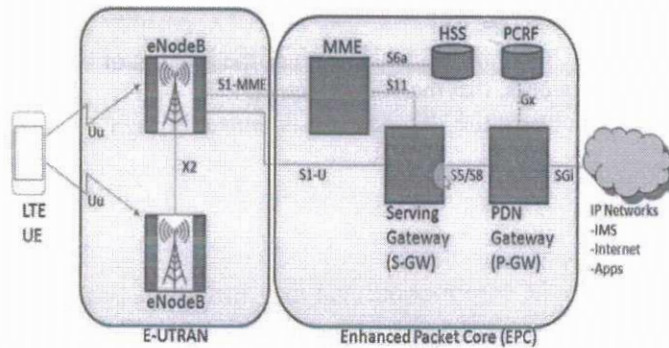
	<p>radio resource management and control, air interface security, mobility procedures and system synchronization</p> <p>UTRAN-(UMTS terrestrial Random Access Network) Is a collective name for NodeB and RNC. UMTS is backward compatible therefore all network elements of GSM and GPRS are there, like MSC, SGSN,GGSN etc. Gateway MSC connects UMTS networks to other Networks.</p>			
<p>XI.</p>	<p>Bluetooth is universal for short-range wireless voice and data communication. It is a Wireless Personal Area Network (WPAN) technology and is used for exchanging data over smaller distances. It operates in the unlicensed, industrial, scientific, and medical (ISM) band from 2.4 GHz to 2.485 GHz. Maximum devices that can be connected at the same time are 7. Bluetooth ranges up to 10 meters. The spreading technique that it uses is FHSS (Frequency-hopping spread spectrum). A Bluetooth network is called a <b>piconet</b> and a collection of interconnected piconets is called <b>scatternet</b></p>  <p>The diagram illustrates the Bluetooth Protocol Architecture, organized into four layers:</p> <ul style="list-style-type: none"> <li><b>Application Layer:</b> Contains Application Profiles.</li> <li><b>Middleware Layer:</b> Contains WAP, TCP/UDP, IP, PPP, AT Command, SDP, Host Controller Interface, and L2CAP.</li> <li><b>Data Link Layer:</b> Contains LMP.</li> <li><b>Physical Layer:</b> Contains Baseband and Bluetooth Radio.</li> </ul> <p>The Host Controller Interface (HCI) is shown as a bridge between the Host and the Bluetooth Radio. The Baseband and Bluetooth Radio are shown as the physical components of the device.</p>	<p>Overall Explanation-3 Diagram-4</p>	<p>7</p>	
<p>XII.</p>	<p>WLAN-IEEE 802.11 (specification)</p> <p>Wireless Local Area Network (WLAN) technology enables wireless data transmission between devices within a limited geographic area, typically a home, office, or public hotspot.</p>	<p>Overall explanation-4 marks Advantages Disadvantages -3 marks</p>	<p>7</p>	

	<p>WLAN uses radio waves to create a network, allowing devices like laptops, smartphones, and tablets to connect to the internet and each other without physical cables. WLANs are commonly implemented using Wi-Fi technology, offering convenience, mobility, and scalability. They have become ubiquitous in modern computing, powering wireless internet access in homes, businesses, airports, and public spaces, fostering connectivity and enabling seamless access to online resources.</p> <p>Advantages</p> <ul style="list-style-type: none"> <li>• They provide clutter-free homes, offices and other networked places.</li> <li>• The LANs are scalable in nature, i.e. devices may be added or removed from the network at greater ease than wired LANs.</li> <li>• The system is portable within the network coverage. Access to the network is not bounded by the length of the cables.</li> <li>• Installation and setup are much easier than wired counterparts.</li> <li>• The equipment and setup costs are reduced.</li> </ul> <p>Disadvantages</p> <ul style="list-style-type: none"> <li>• Since radio waves are used for communications, the signals are noisier with more interference from nearby systems.</li> <li>• Greater care is needed for encrypting information. Also, they are more prone to errors. So, they require greater bandwidth than the wired LANs.</li> <li>• WLANs are slower than wired LANs.</li> </ul>			
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	<b>Basis of</b>	<b>IoT</b>	<b>M2M</b>		
	Abbreviation	Internet of Things	Machine to Machine		
	Intelligence	Devices have objects that are responsible for decision making	Some degree of intelligence is observed in this.		
	Connection type used	The connection is via Network and using various communication types.	The connection is a point to point		
	Communication protocol used	Internet protocols are used such as HTTP,FTP and TELNET	Traditional protocols and communication technology techniques are used		
	Data Sharing	Data is shared between other applications that are used to improve the end-user experience.	Data is shared with only the communicating parties.		
	Internet	Internet connection is required for communication	Devices are not dependent on the Internet.		
XIII.	Type of Communication	It supports cloud communication	It supports point-to-point communication.	Any 7 points. One mark each	7
	Computer System	Involves the usage of both Hardware and Software.	Mostly hardware-based technology		
	Scope	A large number of devices yet scope is large.	Limited Scope for devices.		
	Business Type used	Business 2 Business(B2B) and Business 2 Consumer(B2C)	Business 2 Business (B2B)		
	Open API support	Supports Open API integrations.	There is no support for Open APIs		
	It requires	Generic commodity devices.	Specialized device solutions.		
	Centric	Information and service centric	Communication and device centric.		
	Approach used	Horizontal enabler approach	Vertical system solution approach .		
	Components	Devices/sensors, connectivity, data processing, user interface	Device, area networks, gateway, Application server.		
	Examples	Smart wearables, Big Data and Cloud, etc.	Sensors, Data and Information, etc.		

	<div style="text-align: center;"> <h2>M2M vs. IoT: What's the difference?</h2> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%;">M2M</th> <th style="width: 50%;">IoT</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;"><b>Machines</b></td> <td style="text-align: center;"><b>Sensors</b></td> </tr> <tr> <td style="text-align: center;">Hardware-based</td> <td style="text-align: center;">Software-based</td> </tr> <tr> <td style="text-align: center;">Vertical applications</td> <td style="text-align: center;">Horizontal applications</td> </tr> <tr> <td style="text-align: center;">Deployed in a closed system</td> <td style="text-align: center;">Connects to a larger network</td> </tr> <tr> <td style="text-align: center;">Machines communicating with machines</td> <td style="text-align: center;">Machines communicating with machines, humans with machines, machines with humans</td> </tr> <tr> <td style="text-align: center;">Uses non-IP protocol</td> <td style="text-align: center;">Uses IP protocols</td> </tr> <tr> <td style="text-align: center;">Can use the cloud, but not required to</td> <td style="text-align: center;">Uses the cloud</td> </tr> <tr> <td style="text-align: center;">Machines use point-to-point communication, usually embedded in hardware</td> <td style="text-align: center;">Devices use IP networks to communicate</td> </tr> <tr> <td style="text-align: center;">Often one-way communication</td> <td style="text-align: center;">Back and forth communication</td> </tr> <tr> <td style="text-align: center;">Main purpose is to monitor and control</td> <td style="text-align: center;">Multiple applications; multilevel communications</td> </tr> <tr> <td style="text-align: center;">Operates via triggered responses based on an action</td> <td style="text-align: center;">Can, but does not have to, operate on triggered responses</td> </tr> <tr> <td style="text-align: center;">Limited integration options, devices must have complementary communication standards</td> <td style="text-align: center;">Unlimited integration options, but requires software that manages communications/protocols</td> </tr> <tr> <td style="text-align: center;">Structured data</td> <td style="text-align: center;">Structured and unstructured data</td> </tr> </tbody> </table> </div>	M2M	IoT	<b>Machines</b>	<b>Sensors</b>	Hardware-based	Software-based	Vertical applications	Horizontal applications	Deployed in a closed system	Connects to a larger network	Machines communicating with machines	Machines communicating with machines, humans with machines, machines with humans	Uses non-IP protocol	Uses IP protocols	Can use the cloud, but not required to	Uses the cloud	Machines use point-to-point communication, usually embedded in hardware	Devices use IP networks to communicate	Often one-way communication	Back and forth communication	Main purpose is to monitor and control	Multiple applications; multilevel communications	Operates via triggered responses based on an action	Can, but does not have to, operate on triggered responses	Limited integration options, devices must have complementary communication standards	Unlimited integration options, but requires software that manages communications/protocols	Structured data	Structured and unstructured data			
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<p>XIV.</p>	<p>LTE (Long-Term Evolution) is a 4G wireless communication standard known for its high-speed data transmission and low latency. Its architecture can be represented by a simplified block diagram, which typically consists of the following key components</p>	<p>Block diagram 4 marks</p> <p>Explanation 3 marks</p>	<p>7</p>																													

## 4G | LTE ARCHITECTURE



### User Equipment (UE):

- Represents the end-user device, such as a smartphone, tablet, or modem.
- Contains the LTE modem and the antenna for wireless communication.

### • eNodeB (Evolved NodeB):

- Also known as the base station or cell tower.
- Responsible for radio communication with the UE.
- Handles tasks like radio resource management and handover procedures.
- Connected to the EPC (Evolved Packet Core) via an interface called S1 (for user plane) and X2 (for control plane) for communication with other eNodeBs.

### • Evolved Packet Core (EPC):

- The core network of LTE, responsible for handling data and signaling traffic.
- Comprises several functional elements:
  - **MME (Mobility Management Entity):** Handles UE tracking and signaling for mobility.
  - **SGW (Serving Gateway):** Routes data packets between the UE and the PDN (Packet Data Network).
  - **PGW (Packet Data Network Gateway):** Connects the EPC to external networks, like the internet or private networks.
  - **HSS (Home Subscriber Server):** Stores user subscription and authentication data.
  - **PCRF (Policy and Charging Rules Function):** Enforces QoS policies and handles charging for data usage.

	<ul style="list-style-type: none"> <li>○ <b>DNS (Domain Name System):</b> Resolves domain names to IP addresses.</li> <li>• <b>Public Data Network (PDN):</b> <ul style="list-style-type: none"> <li>• Represents the external networks, such as the internet or enterprise networks, that the UE accesses.</li> <li>• Data traffic between the UE and PDN is routed through the EPC.</li> </ul> </li> <li>• <b>Backhaul Network:</b> Connects eNodeBs to the core network and may include optical fibers, microwave links, or other high-capacity links.</li> </ul>			
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