

Mobile & Wireless Communication (315339)

MSBTE Diploma · K-Scheme · Model Question Paper — Set B · Model Answers

Q.1

a) Frequency reuse and co-channel reuse distance

2 M

Frequency reuse: The technique of using the same set of radio channels (frequencies) in different cells that are separated by a sufficient distance, so that co-channel interference stays within tolerable limits. It increases system capacity with limited spectrum.

Co-channel reuse distance (D): The minimum distance between centres of two cells using the same channel set: $D = R\sqrt{3N}$, where R is cell radius and N is cluster size.

(1 M each)

b) Functions of MSC and BSC

2 M

- **MSC:** Mobile Switching Centre — heart of NSS: sets up, switches and releases calls, handles mobility management, inter-BSC/inter-MSC handover, billing records and interworking with PSTN.
- **BSC:** Base Station Controller — controls a group of BTSs: allocates radio channels, controls power, manages handover between its BTSs, connects BTS to MSC.

(1 M each)

c) MIMO and its advantages

2 M

MIMO (Multiple-Input Multiple-Output) is a wireless technique in which multiple antennas are used at both the transmitter and the receiver to send and receive more than one data stream over the same frequency at the same time, using multipath propagation.

Advantages: (i) higher data rate and capacity through spatial multiplexing; (ii) better reliability / reduced fading through diversity; (iii) improved coverage and spectral efficiency without extra bandwidth.

(Definition 1 M, any two advantages 1 M)

d) Network slicing; types of slices

2 M

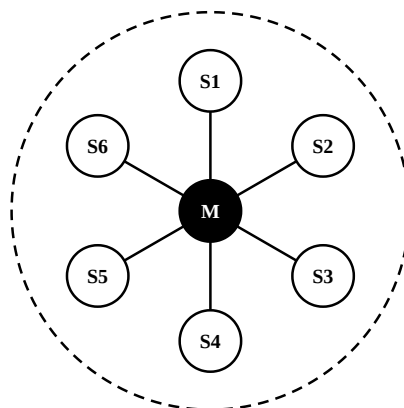
Network slicing: Creation of multiple independent, end-to-end virtual (logical) networks on a common physical 5G infrastructure, each slice optimised for a particular service in terms of data rate, latency and reliability.

Types: eMBB slice (high data rate), URLLC slice (low latency, high reliability), mMTC / massive IoT slice (large number of devices), V2X slice.

(Definition 1 M, any two types 1 M)

e) Bluetooth piconet

2 M



(a) Piconet: 1 master + up to 7 active slaves

Fig.: Bluetooth piconet (left) — M: master, S: slave

A piconet can have **one master and up to seven active slaves** (more slaves, up to 255, can be in parked state).

(Diagram 1 M, number 1 M)

f) Types of interference in cellular system

2 M

- **Co-channel interference** — from cells using the same frequency.
- **Adjacent channel interference** — from channels adjacent in frequency.
- Other: intermodulation interference, inter-symbol interference (multipath), near-far interference, interference from non-cellular sources.

(Two main types 1 M, others 1 M)

g) Four sensors used in smartphone

2 M

Sensor	Use
Accelerometer	Detects motion/tilt — screen rotation, step counting
Gyroscope	Measures rotation — gaming, camera stabilisation
Proximity sensor	Turns screen off when phone is near the ear
Ambient light sensor	Auto-adjusts screen brightness
Magnetometer	Digital compass, maps
GPS receiver	Location and navigation
Fingerprint sensor	Biometric unlock / payments
Camera (image sensor), touch screen	Photos, video calls / user input

(Any four, ½ M each)

Q.2

a) Transmitter section — directional coupler and power sensor

4 M

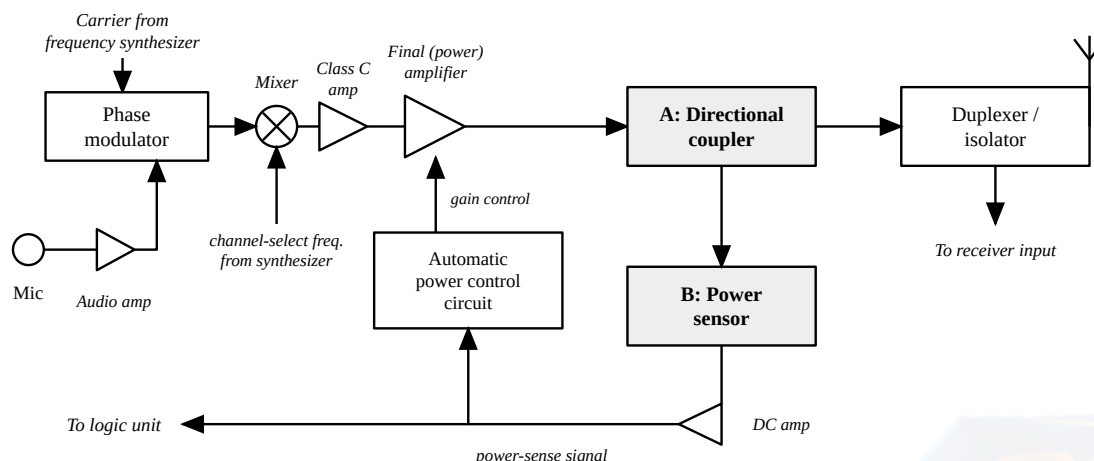


Fig.: Transmitter section of a cellular telephone (A = directional coupler, B = power sensor/detector)

The phase-modulated carrier is mixed to the selected channel frequency, amplified by class C and final power amplifiers and sent through the duplexer to the antenna.

- **Directional coupler (A):** placed between the final power amplifier and duplexer. It passes almost all the RF power to the antenna and takes out (samples) a small, fixed fraction of the forward output power, without disturbing the main line.
- **Power sensor / detector (B):** rectifies the sampled RF from the coupler and converts it into a DC voltage proportional to transmitted power. This DC is amplified and fed to the automatic power control circuit and to the logic unit.
- **Automatic power control:** compares the sensed power with the level ordered by the base station and adjusts the gain of the amplifiers — keeps the output at the required level, saves battery and reduces interference.

(Diagram 2 M, functions 2 M)

b) Compare GSM and IS-95

4 M

Parameter	GSM	IS-95
Modulation	GMSK	QPSK (forward), OQPSK (reverse)
Data rate	270.833 kbps per carrier; 9.6 kbps user data	1.2288 Mcps chip rate; 9.6 / 14.4 kbps user data
Frequency reuse	N = 3 to 7 (typically 4 or 7)	N = 1 (same frequency in every cell)
Handoff	Hard (mobile-assisted)	Soft handoff

(1 M each)

c) Mobile-originated call (mobile to landline)

4 M

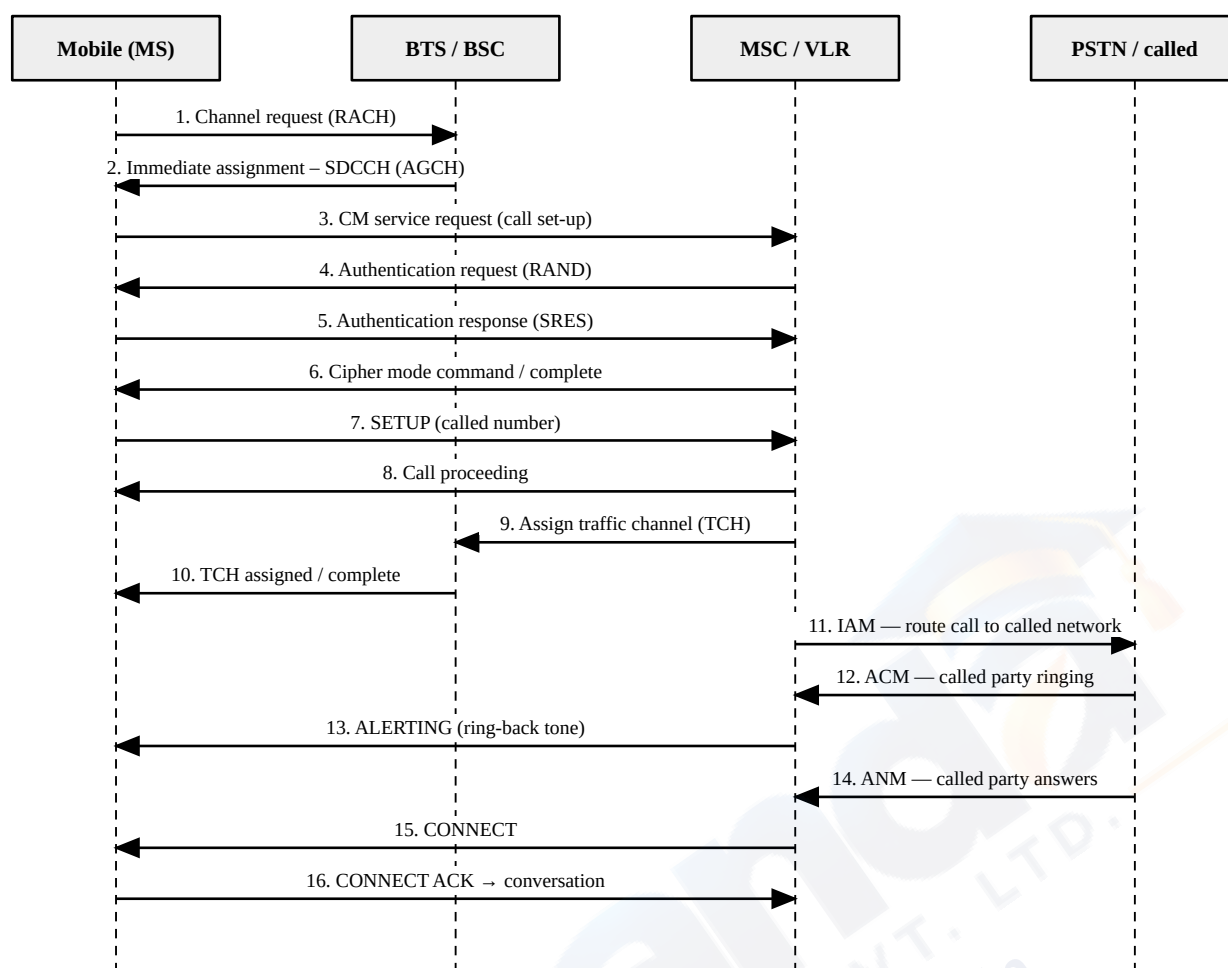


Fig.: Mobile-originated call — signalling sequence (GSM)

- **Access:** MS sends channel request on RACH; BSS allocates SDCCH (immediate assignment on AGCH).
- **Security:** MS sends service request; MSC/VLR performs authentication (RAND → SRES compared) and ciphering is started.
- **Set-up:** MS sends SETUP with the landline number; MSC checks the VLR record and returns call proceeding; a traffic channel is assigned.
- **Routing:** MSC sends IAM to the PSTN exchange; ACM is returned when the landline rings → ALERTING (ring-back) to MS.
- **Connection:** when the called person lifts the handset, ANM → CONNECT to MS → CONNECT ACK; speech flows on TCH. Billing starts at the MSC.

(Diagram 2 M, explanation 2 M)

d) IEEE 802.11a vs 802.11g

4 M

Parameter	IEEE 802.11a	IEEE 802.11g
Year of standard	1999	2003
Frequency band	5 GHz (U-NII)	2.4 GHz (ISM)
Maximum data rate	54 Mbps	54 Mbps

Modulation / PHY	OFDM only	OFDM, plus DSSS/CCK for 802.11b compatibility
Backward compatibility	Not compatible with 802.11b	Compatible with 802.11b
Range (indoor, typical)	Shorter, about 35 m (5 GHz absorbed more by walls)	Longer, about 38 m
Interference	Less (5 GHz band less crowded)	More (microwave ovens, Bluetooth, cordless phones in 2.4 GHz)
Non-overlapping channels	More (12 or more, 20 MHz each)	Only 3 (channels 1, 6, 11)

(Any four points, 1 M each)

Q.3

a) S/I for N = 4 and N = 7 (n = 4, i₀ = 6)

4 M

For a hexagonal system with i₀ first-tier co-channel cells: $S/I = (D/R)^n / i_0 = (\sqrt{3N})^n / i_0$

Cluster size N	$Q = \sqrt{3N}$	Q^4	$S/I = Q^4/6$	$S/I \text{ (dB)} = 10 \log(S/I)$
4	3.464	144	24.00	13.80 dB
7	4.583	441	73.50	18.66 dB

For N = 4, S/I = 13.80 dB < 18 dB — **not acceptable**. For N = 7, S/I = 18.66 dB > 18 dB — acceptable.

Hence a cluster size of N = 7 should be used.

(Formula 1 M, N = 4 1 M, N = 7 1 M, conclusion 1 M)

b) Microcell zone concept

4 M

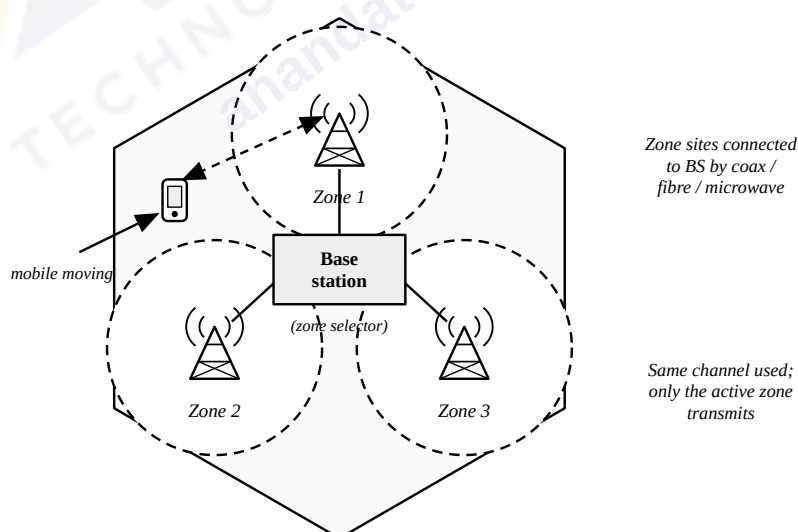


Fig.: Microcell zone concept (zone selector at the base station)

- A cell is divided into several **zones**; each zone has a small zone-site transmitter/receiver, all connected to one base station by coaxial cable, optical fibre or microwave link.
- The mobile is served by the zone which receives its signal strongest. When the mobile moves to another zone **within the same cell**, the base station simply switches the channel to the new zone site (zone selector) — **the channel frequency does not change and no MSC handoff is needed.**
- At any time only the zone where the mobile is present radiates the channel, so co-channel interference is reduced.

Advantages: fewer handoffs, lower interference, larger capacity (a smaller cluster size can be used — capacity can rise about 2.33 times when N reduces from 7 to 3), good coverage along highways and in-building, reduced transmit power.

(Diagram 2 M, explanation 1 M, advantages 1 M)

c) Compare 4G and 5G

4 M

Parameter	4G	5G
Peak data rate	100 Mbps (high mobility) – 1 Gbps (low mobility)	Up to 20 Gbps DL / 10 Gbps UL; 100 Mbps user experienced
Latency	30 – 50 ms	1 ms (URLLC) – 10 ms
Operating spectrum	700 MHz – 2.6 GHz (India: 850, 1800, 2100, 2300 MHz)	Sub-1 GHz, 1–6 GHz (3.3–3.8 GHz) and mmWave 24–100 GHz
Antenna technology	MIMO up to 8×8	Massive MIMO (64T64R) with beamforming

(1 M each)

d) IMT-2020 vision and key capabilities

4 M

Vision: ITU-R IMT-2020 (M.2083) — the 5G vision of a seamlessly connected society beyond 2020 in which people, machines and things are connected anywhere, anytime, supporting eMBB, URLLC and mMTC use cases with much higher performance than IMT-Advanced (4G).

Key capabilities:

Key capability (ITU-R M.2410)	Minimum requirement
Peak data rate	DL 20 Gbit/s, UL 10 Gbit/s
User experienced data rate	DL 100 Mbit/s, UL 50 Mbit/s
Peak spectral efficiency	DL 30 bit/s/Hz, UL 15 bit/s/Hz
User-plane latency	4 ms (eMBB), 1 ms (URLLC)
Control-plane latency	20 ms
Connection density	10 ⁶ devices per km ²

(Vision 1 M, any six capabilities 3 M)

Q.4

a) Role of MME, S-GW and P-GW

4 M

- **MME (Mobility Management Entity):** control-plane node — NAS signalling, authentication of UE with HSS, tracking-area update and paging of idle UE, bearer establishment, selection of S-GW/P-GW, handover signalling.
- **S-GW (Serving Gateway):** routes and forwards user data packets between eNodeB and P-GW; acts as **mobility anchor** during inter-eNodeB handover and for inter-3GPP mobility (2G/3G); **buffers downlink data** for idle UE and triggers paging through MME; lawful interception and charging per UE.
- **P-GW (PDN Gateway):** connects the EPC to external packet data networks (Internet, IMS) through SGi; **allocates IP address** to UE; policy enforcement and QoS (with PCRF), packet filtering, deep packet inspection, charging; anchor for mobility to non-3GPP networks (Wi-Fi).

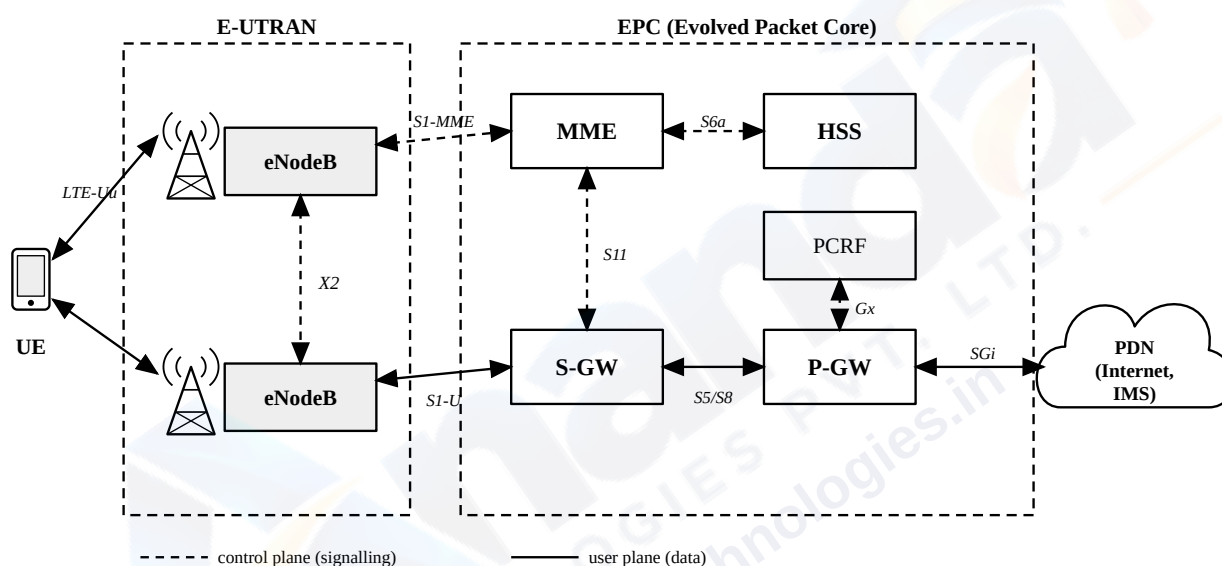


Fig.: LTE (4G) network architecture — EPS = E-UTRAN + EPC

(MME 1 M, S-GW 1.5 M, P-GW 1.5 M)

b) Beamforming in massive MIMO

4 M

Massive MIMO (Advanced Antenna System, AAS) uses a very large antenna array — typically 32 or 64 transmit/receive elements (64T64R) — at the base station.

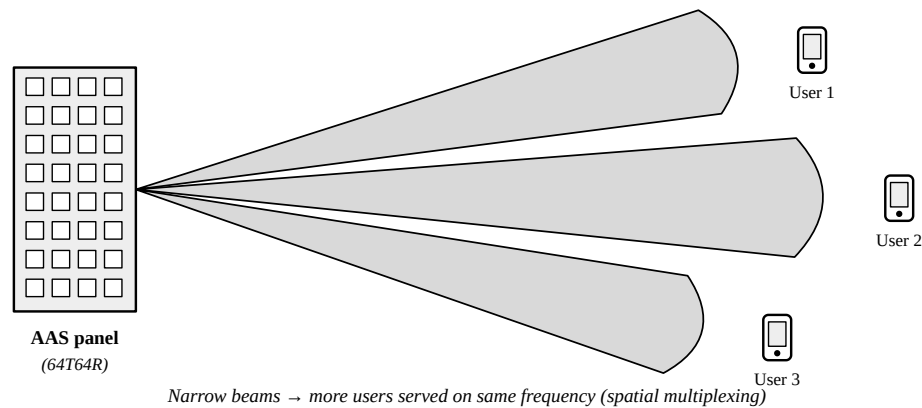


Fig.: Massive MIMO base station forming separate beams towards users

- Each antenna element transmits the same signal with a calculated **phase shift and amplitude weight** (precoding) based on channel estimates of each user.
- The signals add in phase only in the direction of the intended user, forming a narrow **beam**; in other directions they cancel.
- Different users get different beams on the same time-frequency resource — **multi-user MIMO**, so capacity increases many times.
- Beams can be steered electronically in horizontal and vertical directions (3D beamforming) and follow moving users.
- **Benefits:** higher capacity and spectral efficiency, extended coverage (array gain), less interference, better energy efficiency.

(Sketch 2 M, explanation 2 M)

c) Channels per cell for N = 4 (30 MHz, 25 kHz simplex)

4 M

Duplex channel bandwidth = $2 \times 25 \text{ kHz} = 50 \text{ kHz}$

Total number of duplex channels = $30\,000 \text{ kHz} / 50 \text{ kHz} = \mathbf{600 \text{ channels}}$

Channels per cell (N = 4) = $600 / 4 = \mathbf{150 \text{ channels per cell}}$

(For comparison, with N = 7 only $\lfloor 85.71 \rfloor = 85$ channels per cell are available — a smaller cluster gives more channels per cell.)

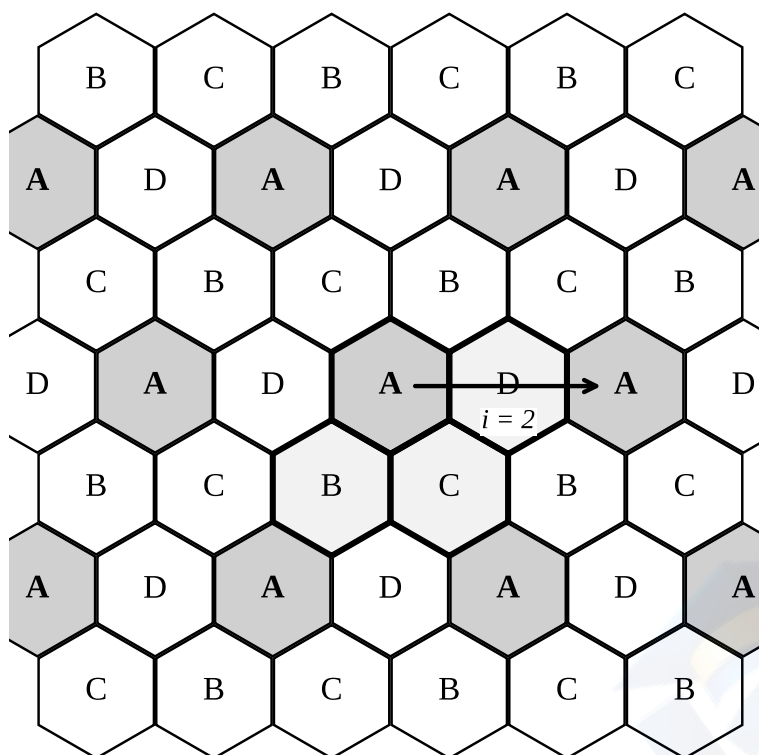


Fig.: Frequency reuse pattern for cluster size $N = 4$ ($i = 2, j = 0$); shaded cells use the same channel set A
(Total channels 1 M, per cell 1 M, pattern 2 M)

d) Advantages of Wi-MAX over WLAN for large areas

4 M

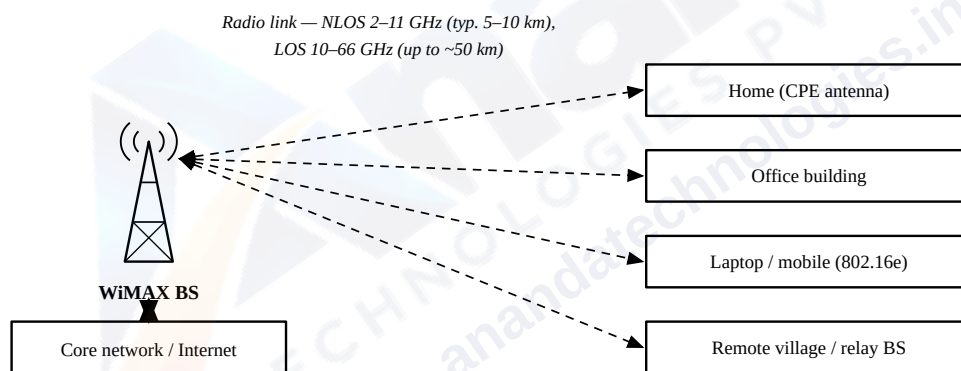


Fig.: WiMAX (IEEE 802.16) — point-to-multipoint broadband over several km

Parameter	Wi-MAX (IEEE 802.16)	WLAN (IEEE 802.11)
Range	Several km — up to ~50 km LOS, 5–10 km NLOS	About 100 m
Data rate	Up to about 70 Mbps shared per sector	54 Mbps (a/g) in a small area
MAC / QoS	Scheduled (grant-based) MAC with QoS classes — UGS, rtPS, nrtPS, BE	Contention-based CSMA/CA, limited QoS
Spectrum	Licensed and unlicensed (2–11 GHz, 10–66 GHz)	Unlicensed 2.4 / 5 GHz only
Users per BS	Hundreds of subscribers	Few tens per AP
Mobility	Supported in 802.16e (vehicular speeds)	Mainly nomadic / local

Therefore Wi-MAX works as a wireless MAN — last-mile broadband for towns and rural areas without laying cables — while WLAN is only for a building/campus.

(Any four advantages, 1 M each)

e) 5G low, mid and high bands

4 M

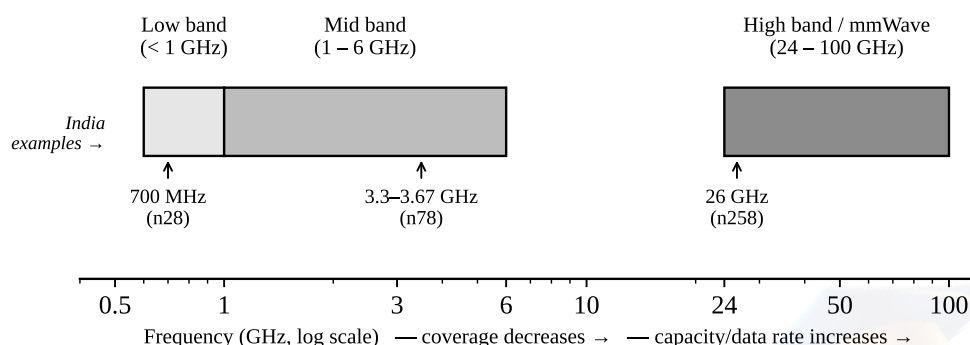


Fig.: 5G (NR) spectrum — low, mid and high (mmWave) bands

Band	Range	Characteristics
Low band	Below 1 GHz (600/700/800 MHz)	Wide coverage (many km), good building penetration; low bandwidth so speed only slightly better than 4G ($\approx$ 50–250 Mbps). Used for rural and IoT coverage.
Mid band	1–6 GHz (mainly 3.3–3.8 GHz C-band)	Balance of coverage and capacity; 50–100 MHz channels; 100 Mbps – 1 Gbps; main 5G band in India (n78) with massive MIMO.
High band (mmWave)	24–100 GHz (India: 26 GHz)	Huge bandwidth (400–800 MHz), multi-Gbps speed and very low latency, but very short range (a few hundred metres), blocked by walls/rain — needs small cells and beamforming.

(1 M each band, diagram 1 M)

Q.5

a) GSM architecture and functions of NSS

6 M

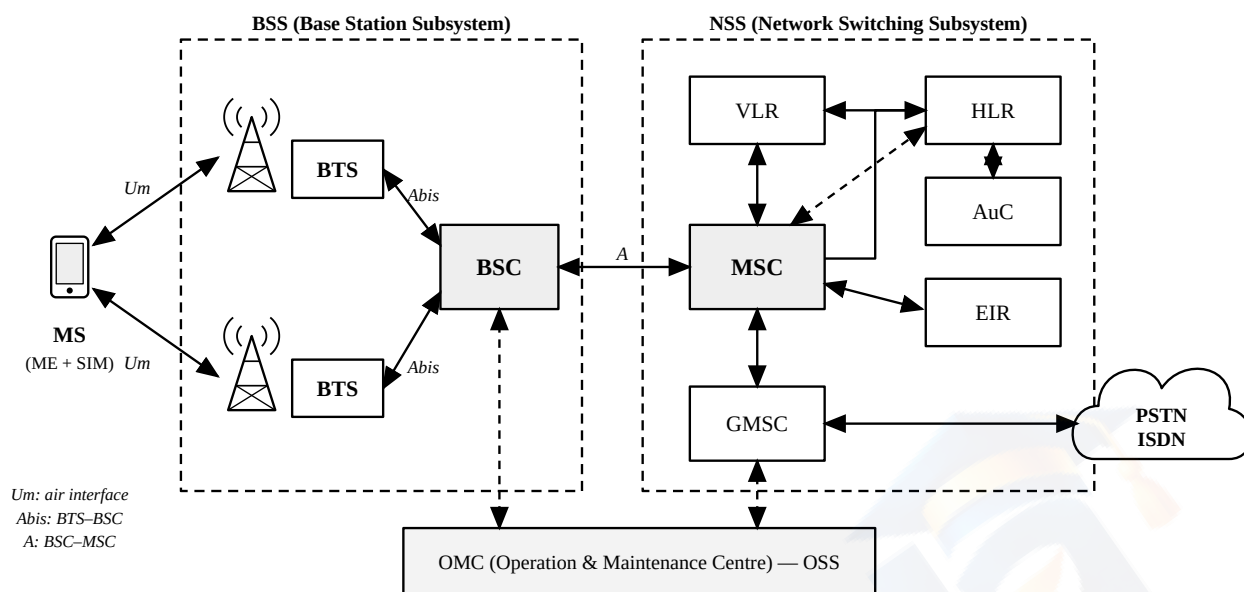


Fig.: GSM network architecture

Network Switching Subsystem (NSS) performs switching of calls between mobile users and between mobile and fixed network users, and manages mobility and subscriber data. It contains:

- **MSC:** Mobile Switching Centre — heart of NSS: sets up, switches and releases calls, handles mobility management, inter-BSC/inter-MSC handover, billing records and interworking with PSTN.
- **GMSC:** Gateway MSC — interface to PSTN/ISDN; interrogates HLR to route incoming calls.
- **HLR:** Home Location Register — permanent database of all subscribers of the operator: IMSI, MSISDN, subscribed services and current location (VLR address).
- **VLR:** Visitor Location Register — temporary database of subscribers currently roaming in the MSC area; stores TMSI, location area; reduces queries to HLR.
- **AuC:** Authentication Centre — stores secret key K_i of every SIM and generates triplets (RAND, SRES, K_c) for authentication and ciphering.
- **EIR:** Equipment Identity Register — list of IMEIs: white (valid), grey (monitored) and black (stolen/barred) handsets.

Functions of NSS: call set-up, switching and routing; mobility management (location update, paging); authentication and ciphering; inter-BSC and inter-MSC handover; charging/billing records; interworking with PSTN/ISDN; supplementary services and SMS.

(Diagram 2 M, NSS entities 2 M, functions 2 M)

b) Significance of 5G and enabling technologies

6 M

Significance of 5G:

- Multi-gigabit speeds and 1 ms latency make real-time applications such as AR/VR, cloud gaming, autonomous vehicles and remote surgery possible.

- Supports a million devices per km² — backbone of IoT, smart cities, smart agriculture and Industry 4.0.
- Network slicing gives tailored networks to industries; private 5G for factories, ports and campuses.
- Better spectral and energy efficiency lowers cost per bit; fixed wireless access gives home broadband without fibre.

Enabling technologies:

- **Millimetre wave (mmWave):** Uses 24–100 GHz bands where very wide bandwidths (400 MHz or more) are free — gives multi-Gbps rates.
- **Small cells:** Low-power femto/pico/micro cells placed densely (lamp posts, buildings) to overcome mmWave range limits and increase capacity.
- **Massive MIMO:** Base stations with 64 or more antenna elements serve many users on the same frequency at the same time (spatial multiplexing).
- **Beamforming:** Focuses energy as a narrow beam toward each user — increases range and reduces interference.
- **Full duplex:** Transmit and receive on the same frequency at the same time using self-interference cancellation (research stage).
- **SDN / NFV and network slicing:** Network functions run as software on cloud servers; slices are created on demand for different services.

(Significance 2 M, any four technologies 4 M)

c) V2X communication

6 M

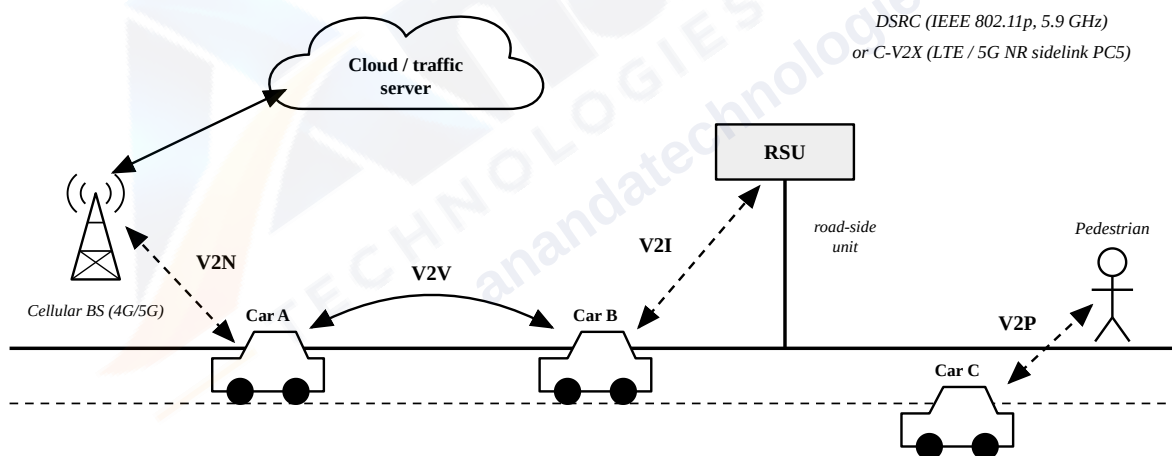


Fig.: Vehicular (V2X) communication — V2V, V2I, V2P and V2N

- **V2V (vehicle-to-vehicle):** vehicles directly exchange position, speed and braking information — collision warning, emergency brake light, lane-change and blind-spot warning, platooning.
- **V2I (vehicle-to-infrastructure):** communication with road-side units, traffic lights and toll gates — signal phase and timing, speed advisory, electronic toll, road-work warnings.
- **V2P (vehicle-to-pedestrian):** warnings between vehicles and pedestrians/cyclists through their smartphones or wearables.

- **V2N (vehicle-to-network):** through the cellular network to the cloud — traffic and route information, infotainment, software updates, remote diagnostics.

Technologies: (i) **DSRC** — IEEE 802.11p (WAVE) in the 5.9 GHz band, direct ad hoc communication with low latency; (ii) **C-V2X** — 3GPP LTE-V2X (Rel-14) and 5G NR-V2X (Rel-16) using the PC5 sidelink for direct communication and the Uu interface via base station.

(Diagram 2 M, four modes 2 M, technologies 2 M)

Q.6

a) Radio aspects of GSM

6 M

Radio aspect	GSM specification
Frequency band (GSM-900)	Uplink (MS → BTS) 890–915 MHz; downlink (BTS → MS) 935–960 MHz
Duplex spacing	45 MHz (FDD)
Carrier (channel) spacing	200 kHz → 124 carrier pairs
Multiple access	FDMA + TDMA, 8 time slots per carrier
TDMA frame / slot	Frame 4.615 ms; time slot 576.9 μs (156.25 bit periods)
Modulation	GMSK (BT = 0.3)
Gross bit rate per carrier	270.833 kbps
Speech coding	RPE-LTP full-rate codec, 13 kbps (22.8 kbps after channel coding)
Frequency hopping	Slow frequency hopping, 217 hops/s
Cell radius	Up to 35 km (timing advance limit)
Power control & DTX	Adaptive power control and discontinuous transmission save battery and reduce interference
Equalisation	Adaptive equaliser handles multipath delay spread (about 16 μs)

(Any eight, ¾ M each)

b) LTE vs LTE-Advanced

6 M

Parameter	LTE	LTE-Advanced
Generation / 3GPP release	Release 8/9; often called 3.9G (pre-4G)	Release 10 onwards; true 4G (meets IMT-Advanced)
Peak data rate	DL 300 Mbps, UL 75 Mbps	DL 1 Gbps (up to 3 Gbps), UL 500 Mbps (up to 1.5 Gbps)
Channel bandwidth	1.4 to 20 MHz	Up to 100 MHz (5 × 20 MHz)
MIMO	Up to 4 × 4 in downlink	Up to 8 × 8 DL, 4 × 4 UL
Carrier aggregation	Not supported (single carrier)	Up to 5 component carriers aggregated
Peak spectral efficiency	DL 15 bit/s/Hz, UL 3.75 bit/s/Hz	DL 30 bit/s/Hz, UL 15 bit/s/Hz

Other features	OFDMA/SC-FDMA, all-IP EPC	Adds CoMP, relay nodes, HetNet / eICIC
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(1 M each parameter)

c) NFC — modes and services

6 M

NFC (Near Field Communication) is a very short-range (up to about 4–10 cm) wireless technology working at **13.56 MHz** by magnetic induction, with data rates of 106, 212 or 424 kbps (ISO/IEC 18092, 14443). Communication starts simply by touching/tapping two devices.

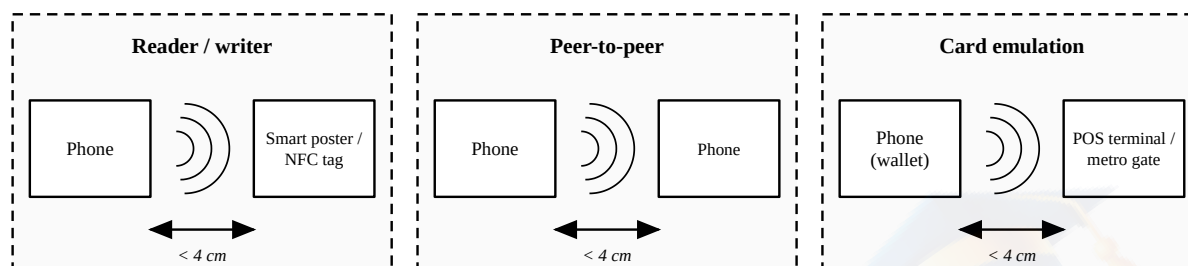


Fig.: NFC operating modes (13.56 MHz, range ≤ 10 cm)

- **Reader/writer mode:** the phone reads or writes passive NFC tags (smart posters, product labels).
- **Peer-to-peer mode:** two NFC devices exchange data — contacts, photos, pairing information.
- **Card emulation mode:** the phone behaves like a contactless smart card for payment, ticket or access card.

NFC services:

- **Contactless payment:** tap-to-pay with phone or card at POS terminal; card details are tokenised and stored in a secure element.
- **Transport ticketing:** metro/bus cards and mobile tickets — tap at the gate.
- **Access control:** office doors, hotel rooms, car keys.
- **Smart posters / information:** tap a tag to open a URL, menu or product details.
- **Device pairing:** quick Bluetooth/Wi-Fi pairing of speakers and headphones.
- **Healthcare and identity:** patient tags, e-passports.

(Definition 1 M, modes 2 M, four services 3 M)

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