

Mobile & Wireless Communication (315339)

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

Q.1**a) Cell, cluster and cluster size formula**

2 M

Cell: The small geographical area covered by one base station is called a cell; it is drawn as a hexagon.

Cluster: A group of N adjacent cells which together use the complete set of available channels (each cell gets a different channel group) is called a cluster. The cluster pattern is repeated to cover the whole area.

Cluster size: $N = i^2 + ij + j^2$, where i and j are non-negative integers (shift parameters). Valid values: $N = 1, 3, 4, 7, 9, 12, 13 \dots$

(Definitions 1 M, formula 1 M)

b) Functions of AuC and EIR

2 M

- **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.

(1 M each)

c) Define beamforming

2 M

Beamforming is a signal-processing technique used with an antenna array in which the phase (and amplitude) of the signal fed to each antenna element is adjusted so that the signals add constructively in the direction of the desired user and cancel in other directions. The radiated energy is thus focused as a narrow, steerable beam toward the user, improving signal strength and reducing interference.

(Definition 2 M)

d) Three usage scenarios of IMT-2020

2 M

- **eMBB** — enhanced Mobile Broadband
- **URLLC** — Ultra-Reliable and Low-Latency Communications
- **mMTC** — massive Machine-Type Communications

(Any three, 2 M)

e) Four features of Bluetooth

2 M

- IEEE 802.15.1 short-range wireless (WPAN) technology.
- Operates in 2.4 GHz ISM band (2.402–2.480 GHz), 79 channels of 1 MHz.
- Frequency hopping spread spectrum at 1600 hops/s — robust against interference.
- Range about 10 m (class 2); up to 100 m (class 1).

- Data rate 1 Mbps (basic rate, GFSK); 2–3 Mbps with EDR.

(Any four, $\frac{1}{2}$ M each)

f) Co-channel interference

2 M

Co-channel interference (CCI): Interference between signals of cells that use the **same set of frequencies** (co-channel cells) in different clusters. It cannot be removed by increasing transmitter power, because the interfering power also increases.

Method to reduce: Increase the co-channel reuse distance D (larger cluster size N), or use cell sectoring with directional antennas.

(Definition 1 M, method 1 M)

g) 5G low band and mid band

2 M

Band	Frequency range	Example in India
Low band	Below 1 GHz (600–900 MHz)	700 MHz (band n28)
Mid band	1 GHz – 6 GHz (mainly 3.3–3.8 GHz)	3300–3670 MHz (band n78)

(1 M each band)

Q.2

a) Block diagram of mobile phone unit

4 M

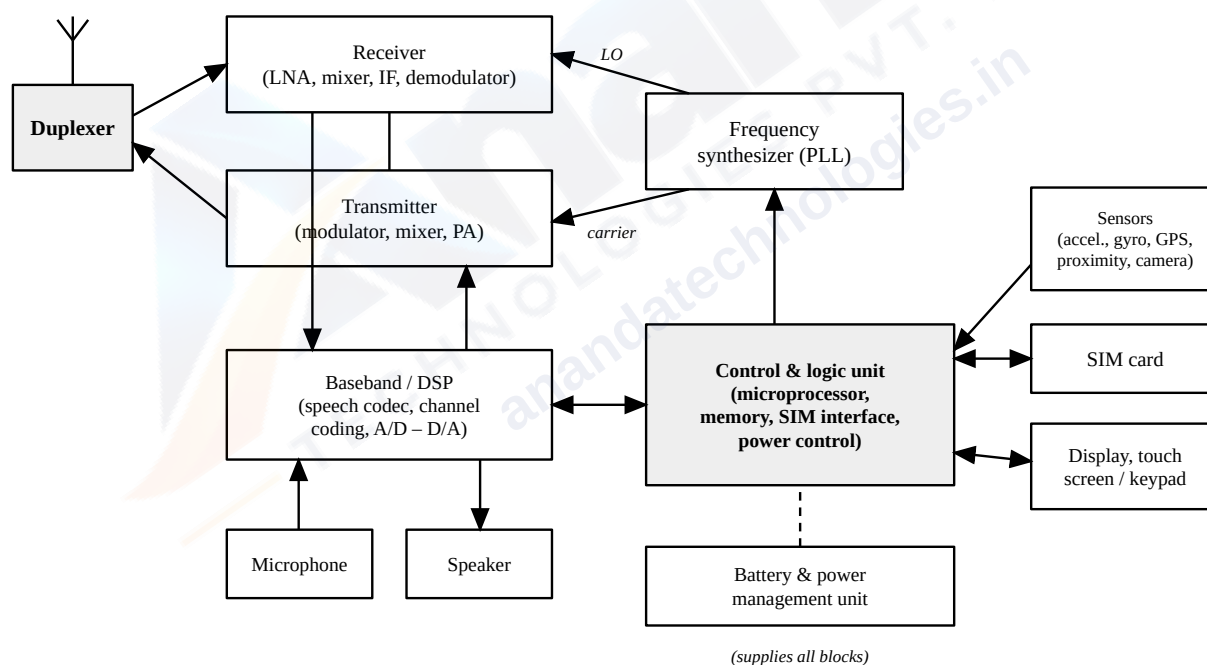


Fig.: Block diagram of a mobile (cellular) telephone unit

- **Duplexer:** allows the single antenna to be used for transmission and reception at the same time by separating transmit and receive frequencies.
- **Receiver:** amplifies (LNA), down-converts (mixer + LO from synthesizer), filters and demodulates the received RF signal to baseband.

- **Transmitter:** modulates the baseband signal on the carrier, up-converts and amplifies it in the power amplifier (power level set by control unit).
- **Frequency synthesizer:** PLL that generates the exact carrier and local-oscillator frequencies of the channel ordered by the network.
- **Control & logic unit:** microprocessor with memory; controls all blocks, handles signalling, SIM interface, display/keypad and power control.
- **Baseband/DSP:** A/D–D/A conversion, speech coding, channel coding, encryption.

(Diagram 2 M, any four blocks ½ M each)

b) Compare AMPS and GSM

4 M

Parameter	AMPS	GSM
Generation	1G	2G
Multiple access	FDMA	TDMA / FDMA (8 slots per carrier)
Channel bandwidth	30 kHz	200 kHz
Modulation	FM (voice), FSK (signalling)	GMSK

(1 M each parameter)

c) GSM architecture and function of BSS

4 M

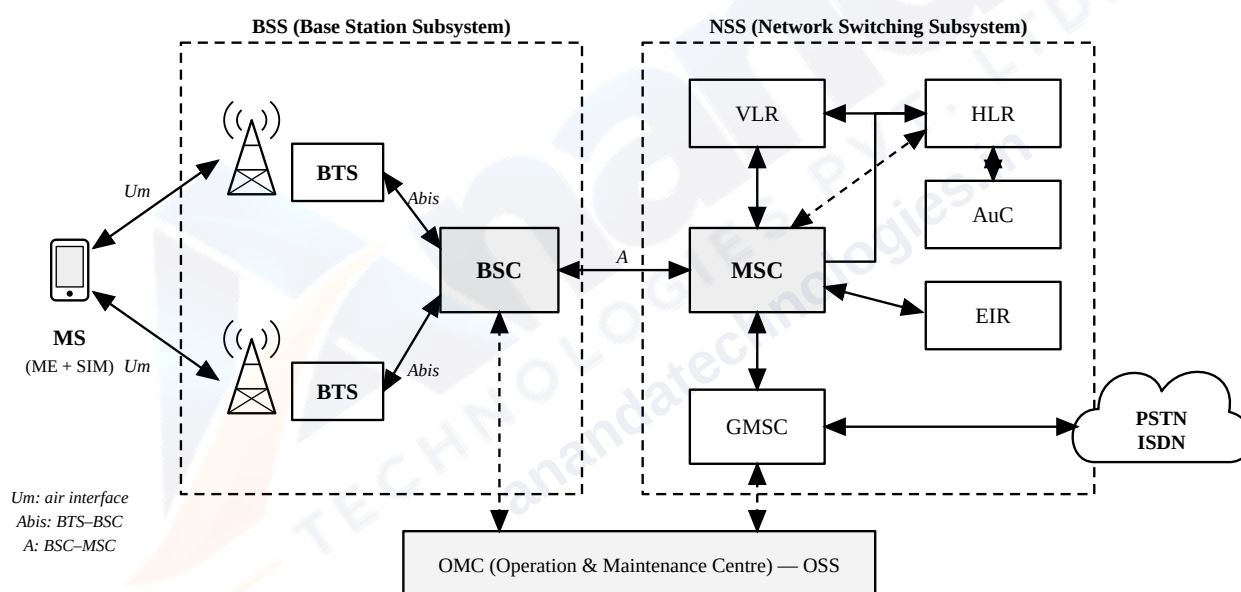


Fig.: GSM network architecture

Base Station Subsystem (BSS) is the radio part of GSM. It consists of BTS and BSC.

- Base Transceiver Station — radio transceivers and antennas of a cell; handles the air interface (Um): modulation, channel coding, ciphering, frequency hopping.
- Base Station Controller — controls a group of BTSs: allocates radio channels, controls power, manages handover between its BTSs, connects BTS to MSC.
- BSS performs radio resource management: channel allocation, power control, frequency hopping and handover between cells of the same BSC.
- It also transcodes 13 kbps speech to 64 kbps (TRAU) for the MSC.

(Diagram 2 M, BSS functions 2 M)

d) IEEE 802.11 architecture

4 M

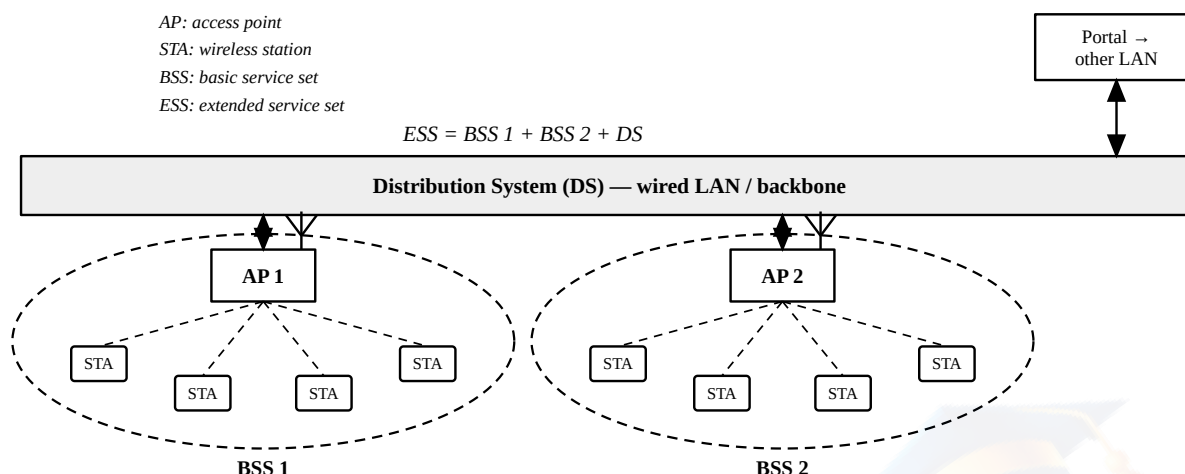


Fig.: IEEE 802.11 architecture — BSS, ESS and distribution system

- **Station (STA):** any device with an 802.11 wireless interface (laptop, phone).
- **Access Point (AP):** a station that provides access to the distribution system; acts as a bridge between wireless and wired LAN.
- **BSS (Basic Service Set):** the group of stations served by one AP (one coverage area). Without an AP, stations form an independent BSS (ad hoc).
- **Distribution System (DS):** the backbone (usually wired Ethernet) that interconnects APs of different BSSs.
- **ESS (Extended Service Set):** two or more BSSs connected through the DS; appears as a single LAN so a station can roam between APs. A **portal** connects the ESS to other LANs.

(Diagram 2 M, explanation 2 M)

Q.3

a) Cluster size for $i = 2$, $j = 1$, reuse pattern and reuse distance ($R = 1.5$ km)

4 M

Cluster size: $N = i^2 + ij + j^2 = 2^2 + (2)(1) + 1^2 = 4 + 2 + 1 = 7$

Reuse distance: $D = R\sqrt{3N} = 1.5 \times \sqrt{3 \times 7} = 1.5 \times \sqrt{21} = 1.5 \times 4.583 = 6.87$ km (co-channel reuse ratio $Q = D/R = 4.583$)

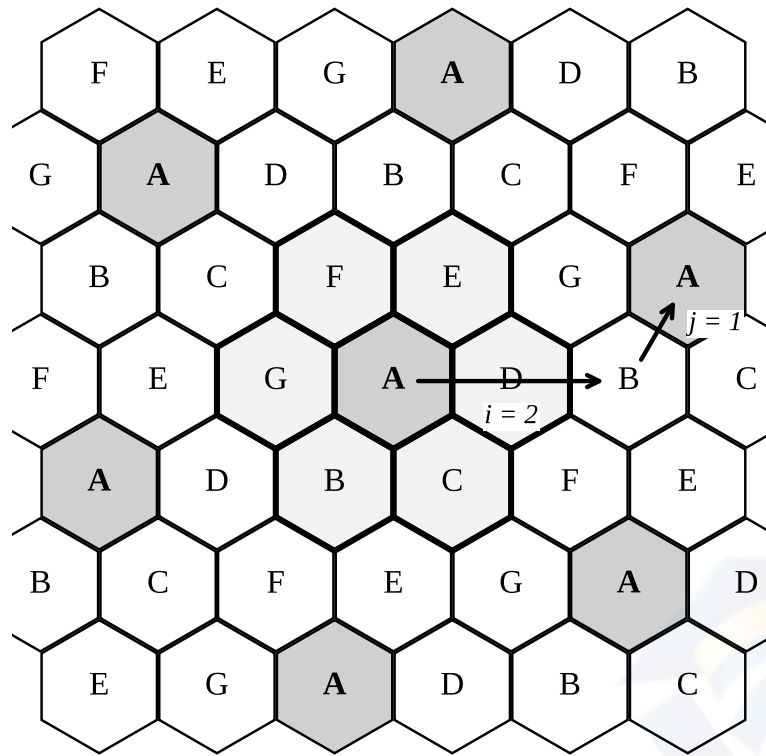


Fig.: Frequency reuse pattern for cluster size $N = 7$ ($i = 2, j = 1$); shaded cells use the same channel set A

To locate a co-channel cell: move $i = 2$ cells along a chain of hexagons, turn 60° anticlockwise and move $j = 1$ cell. All cells marked A use the same channel set.

(N 1 M, D 1 M, pattern 2 M)

b) Mobile-originated call procedure

4 M

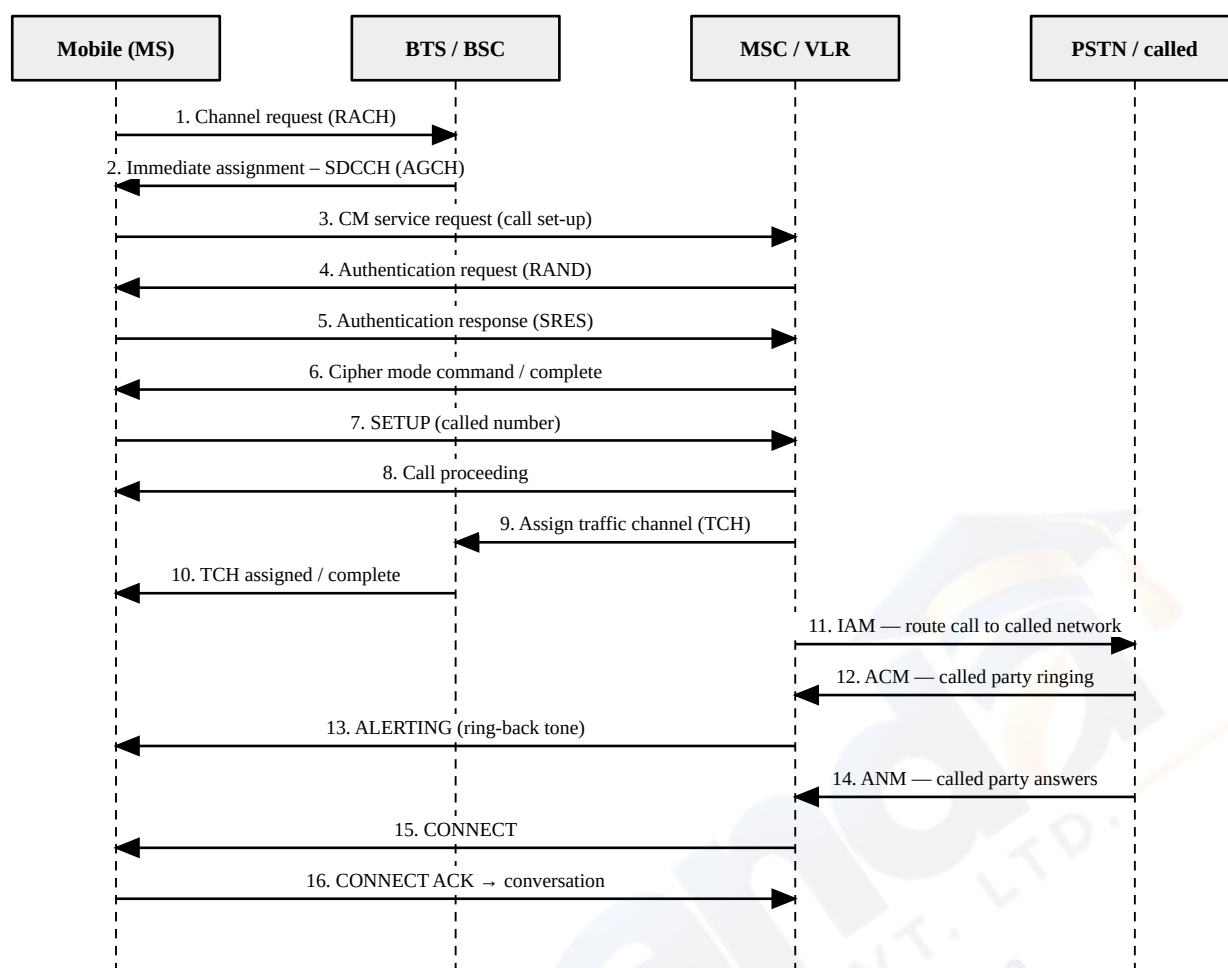


Fig.: Mobile-originated call — signalling sequence (GSM)

- MS sends a **channel request** on RACH; BSS assigns a signalling channel (SDCCH) through AGCH.
- MS sends a **CM service request**; MSC/VLR **authenticates** the MS (RAND/SRES using AuC triplets) and starts **ciphering**.
- MS sends **SETUP** with the dialled number; MSC checks subscription in VLR and replies **call proceeding**.
- MSC asks BSS to assign a **traffic channel (TCH)**; MSC routes the call (IAM) to the PSTN/called network.
- Called phone rings: **ALERTING** (ring-back tone) is sent to MS; when called party answers, **CONNECT** is sent and acknowledged — conversation starts.

(Diagram 2 M, steps 2 M)

c) Compare 3G and 4G

4 M

Parameter	3G	4G
Peak data rate	384 kbps – 2 Mbps (HSPA: up to 14.4 Mbps)	100 Mbps (high mobility) – 1 Gbps (low mobility)
Multiple access	CDMA (WCDMA)	OFDMA (DL), SC-FDMA (UL)

Switching / core	Circuit (voice) + packet (data)	All-IP packet switching (EPC)
Channel bandwidth	5 MHz (WCDMA), 1.25 MHz (CDMA2000)	1.4, 3, 5, 10, 15, 20 MHz (up to 100 MHz with carrier aggregation)

(1 M each parameter)

d) Network slicing in 5G

4 M

Network slicing divides one physical 5G network into several independent, isolated, end-to-end **logical networks (slices)**. Each slice has its own resources and characteristics (data rate, latency, reliability, security) suited to one type of service. It is made possible by SDN, NFV and the cloud-native 5G core.

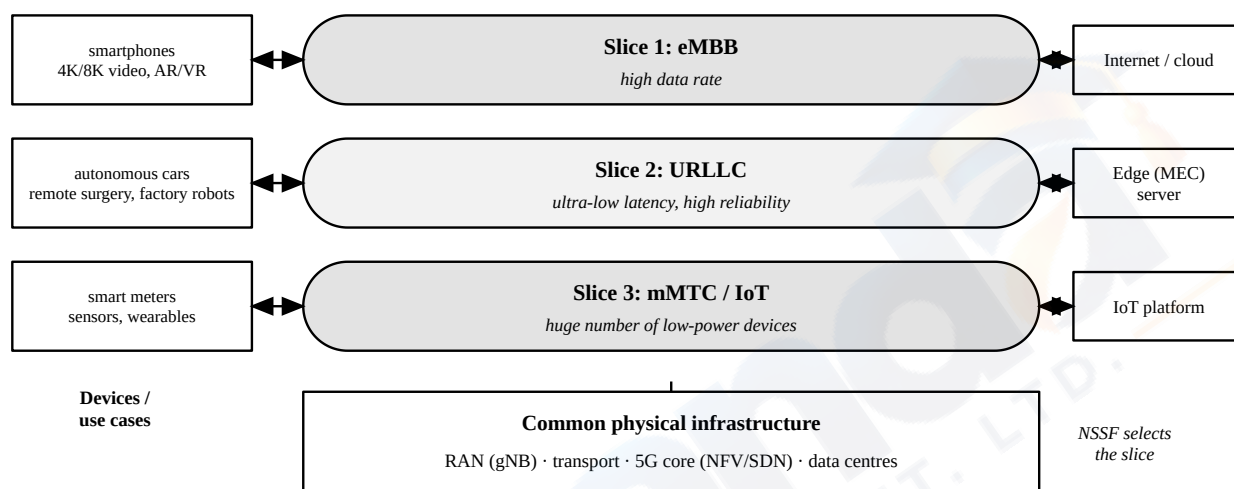


Fig.: Network slicing — several logical end-to-end networks on one physical 5G network

- **eMBB slice** — high bandwidth for smartphones, video, AR/VR.
- **URLLC slice** — very low latency and high reliability for autonomous vehicles, remote surgery, factory automation.
- **mMTC/IoT slice** — supports a huge number of low-power devices like smart meters and sensors.
- The **NSSF** selects the slice for each user; slices share RAN, transport and core but do not affect one another.

(Explanation 2 M, sketch 2 M)

Q.4

a) LTE architecture — eNodeB, MME, HSS

4 M

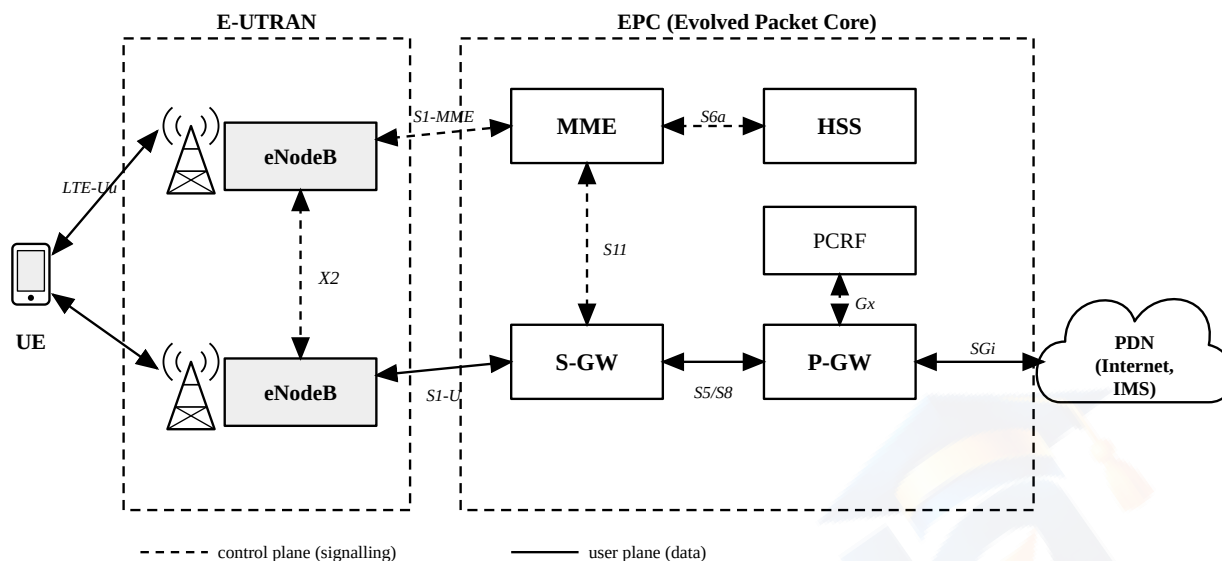


Fig.: LTE (4G) network architecture — EPS = E-UTRAN + EPC

- **eNodeB:** LTE base station; performs all radio functions — radio resource management, scheduling, admission control, header compression, encryption and handover (X2 interface between eNodeBs). No separate controller (RNC/BSC) is needed.
- **MME (Mobility Management Entity):** main control node of EPC — NAS signalling, authentication with HSS, tracking area/paging of idle UE, bearer set-up, selection of S-GW/P-GW.
- **HSS (Home Subscriber Server):** central database of subscriber profiles and security keys (like HLR + AuC); gives authentication vectors and user location to MME.
- S-GW and P-GW carry user data; P-GW connects the network to the Internet (PDN).

(Diagram 2 M, functions 2 M)

b) Adjacent channel interference and reduction

4 M

Adjacent channel interference (ACI) is the interference caused by signals of channels that are **adjacent in frequency** to the desired channel. Because practical receiver filters are not ideal, part of the neighbouring channel energy leaks into the pass-band. It is severe in the **near-far** case, when a mobile close to the base station transmits on an adjacent channel while the desired mobile is far away.

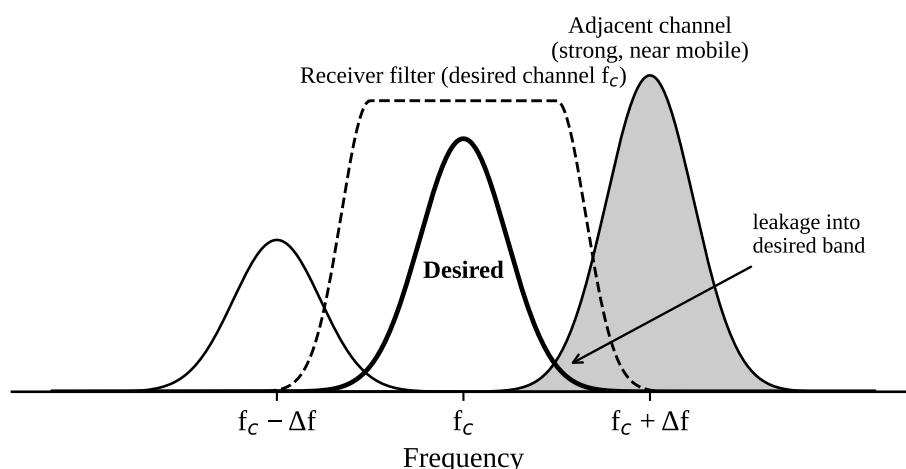


Fig.: Adjacent channel interference — energy of the neighbouring channel falls inside the receiver filter

Methods to reduce ACI:

- Careful filtering — sharp-cutoff receiver filters.
- Proper channel assignment — channels within a cell are separated by N channels (not adjacent ones).
- Guard bands between channels.
- Power control so that near mobiles do not transmit excessive power.
- Avoid assigning adjacent channels to neighbouring cells.

(Explanation 2 M, any three methods 2 M)

c) Handoff

4 M

Handoff (handover) is the process of transferring an ongoing call from one base station (or channel) to another when the mobile moves into a new cell, without interrupting the call.

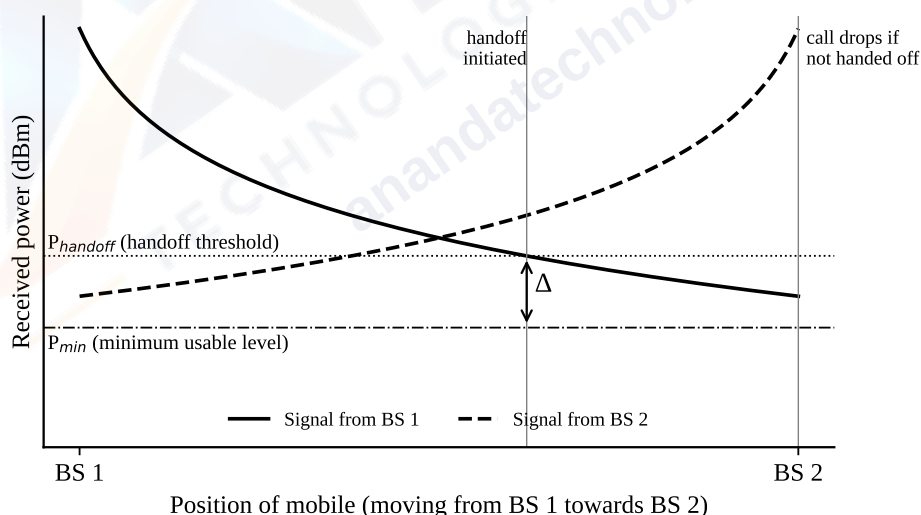


Fig.: Handoff — received signal level as the mobile moves from BS 1 to BS 2

When the signal from the serving BS falls to the handoff threshold P_{handoff} , the MSC starts handoff. The margin $\Delta = P_{\text{handoff}} - P_{\text{min}}$ must be chosen properly: too small → calls drop; too large → unnecessary handoffs.

Hard handoff	Soft handoff
“Break before make” — old link released before new one is set up.	“Make before break” — new link set up before old one is released.
Mobile connected to only one BS at a time.	Mobile connected to two or more BSs simultaneously.
Used in FDMA/TDMA systems (AMPS, GSM).	Used in CDMA systems (IS-95, WCDMA).
Momentary break; higher call-drop chance.	No break; better call quality but uses more resources.

(Explanation with sketch 2 M, differences 2 M)

d) Vehicular communication applications; forward collision warning

4 M

Applications:

- Forward collision warning and emergency electronic brake light
- Intersection movement assist / blind-spot and lane-change warning
- Traffic signal information, green-light speed advisory (V2I)
- Platooning of trucks and cooperative adaptive cruise control
- Pedestrian safety alerts (V2P), electronic toll and parking

Forward collision warning (V2V): Every vehicle broadcasts a basic safety message about 10 times per second containing its position, speed, heading and braking status (DSRC 5.9 GHz or C-V2X sidelink). A following vehicle receives these messages, calculates the time-to-collision with the vehicle ahead and, if it falls below a safe limit (e.g., the car ahead brakes suddenly or is hidden by a truck), warns the driver by sound/display or applies the brakes automatically. Thus accidents are avoided even when the hazard is not in the driver’s line of sight.

(Applications 2 M, description 2 M)

e) Challenges in 5G spectrum allocation and management in India

4 M

- **High spectrum cost:** very high auction reserve prices increase the financial burden on operators and slow down roll-out.
- **Limited mid-band:** only about 3300–3670 MHz is available in the C-band; parts of the band are used by satellite and other services, so contiguous 100 MHz blocks are scarce.
- **mmWave limitations:** 26 GHz has very short range and poor wall penetration — needs very dense small cells.
- **Backhaul and fibre:** a large share of towers is not fibre-connected; small cells need fibre backhaul.
- **Interference / coexistence:** with satellite earth stations and radio altimeters near airports (restrictions near airports), and with defence users.
- **Right of way and infrastructure:** permissions for poles, street furniture and power supply for small cells.
- **Rural coverage and return on investment** — low ARPU makes rural deployment costly; low band (700 MHz) must be used.

- **Spectrum harmonisation and refarming** of 2G/3G bands; policy for unlicensed / enterprise (captive) networks.

(Any four challenges, 1 M each)

Q.5

a) PLL frequency synthesizer; divider ratio for 890.2 MHz

6 M

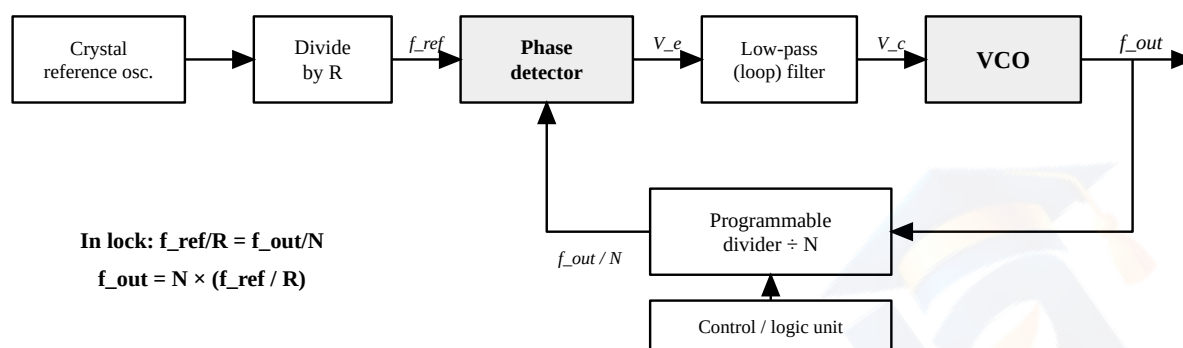


Fig.: PLL frequency synthesizer of a mobile unit

- **Crystal reference oscillator:** very stable fixed frequency; divided by R to give f_{ref} equal to the channel spacing.
- **Phase detector:** compares the phase of f_{ref} with f_{out}/N and produces an error voltage proportional to the phase difference.
- **Low-pass (loop) filter:** removes high-frequency components and gives a smooth DC control voltage; decides lock time and stability.
- **VCO:** voltage-controlled oscillator whose output frequency changes with the control voltage — this is the synthesizer output.
- **Programmable divider $\div N$:** divides VCO output by N; N is loaded by the **control/logic unit** according to the channel ordered by the base station.
- In lock the two inputs of phase detector are equal: $f_{\text{out}}/N = f_{\text{ref}} \rightarrow f_{\text{out}} = N \cdot f_{\text{ref}}$. Changing N by 1 changes the output by one channel spacing.

Numerical: $f_{\text{ref}} = 200 \text{ kHz}$, $R = 1$, $f_{\text{out}} = 890.2 \text{ MHz} = 890\,200 \text{ kHz}$

$N = f_{\text{out}} / f_{\text{ref}} = 890\,200 / 200 = \mathbf{4451}$. (Next channel 890.4 MHz needs $N = 4452$.)

(Diagram 2 M, explanation 2 M, numerical 2 M)

b) IMT-2020 vision, usage scenarios and technical requirements

6 M

Vision: IMT-2020 is the ITU-R framework (Recommendation M.2083, “IMT for 2020 and beyond”) for 5G. Its vision is a fully connected society — connecting not only people but also machines and things — with very high data rates, near-zero latency, massive connectivity, high reliability and energy efficiency. 3GPP 5G NR meets IMT-2020 requirements.

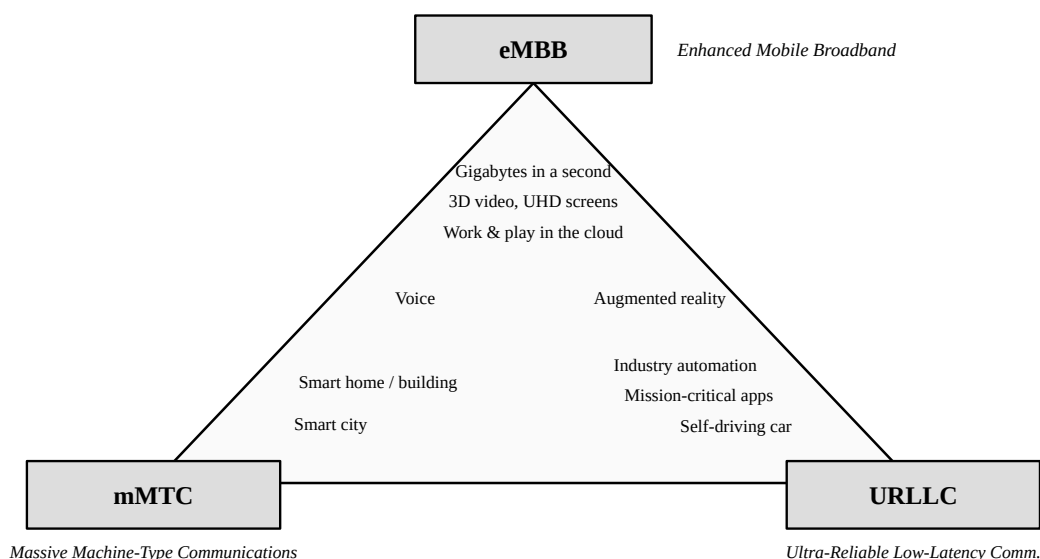


Fig.: IMT-2020 usage scenarios (ITU-R M.2083)

- **eMBB (enhanced Mobile Broadband):** very high data rates and capacity for human-centric use — 4K/8K video, AR/VR, cloud gaming, hotspots and wide-area coverage.
- **URLLC (Ultra-Reliable Low-Latency Communications):** 1 ms latency and very high reliability — autonomous vehicles, remote surgery, industrial robot control, smart grid protection.
- **mMTC (massive Machine-Type Communications):** a very large number ($10^6/\text{km}^2$) of low-cost, low-power devices sending small data — smart meters, sensors, wearables, smart agriculture.

Key technical requirements (any six):

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
Mobility	Up to 500 km/h (high-speed train)
Area traffic capacity	10 Mbit/s per m^2 (indoor hotspot)

(Vision 1 M, usage scenarios with diagram 2 M, requirements 3 M)

c) GSM logical channels

6 M

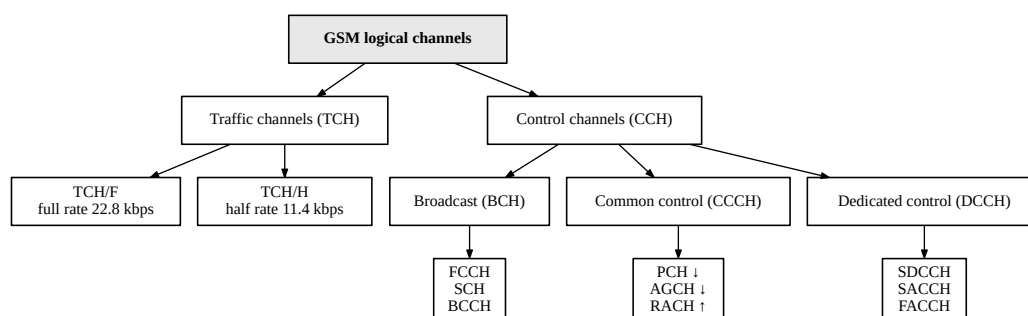


Fig.: Classification of GSM logical channels

A) Traffic channels (TCH) carry user speech or data:

- **TCH/F** — full-rate: 13 kbps speech (22.8 kbps gross) or data up to 9.6 kbps.
- **TCH/H** — half-rate: 11.4 kbps gross; doubles the number of users per carrier.

B) Control channels carry signalling:

- **Broadcast channels (BCH, downlink):** *FCCH* — frequency correction, lets MS lock to carrier; *SCH* — frame synchronisation and BTS identity (BSIC); *BCCH* — cell information (LAI, cell ID, neighbour list, access parameters).
- **Common control channels (CCCH):** *PCH* (down) — pages the MS for incoming call; *RACH* (up) — random access request from MS; *AGCH* (down) — grants a dedicated channel (SDCCH) to MS.
- **Dedicated control channels (DCCH):** *SDCCH* — call set-up, authentication, location update, SMS; *SACCH* — slow associated: measurement reports, power control, timing advance; *FACCH* — fast associated: steals TCH bursts for urgent signalling such as handover.

(Chart 2 M, traffic channels 1 M, control channels 3 M)

Q.6

a) 5G architecture; gNB, AMF, SMF, UPF; advantages over 4G

6 M

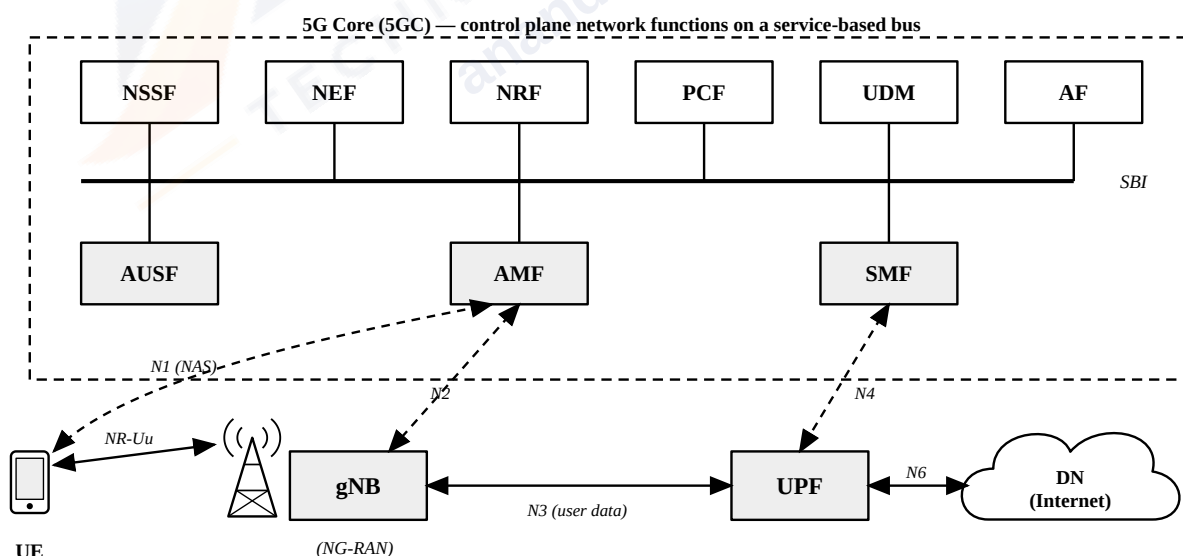


Fig.: 5G system architecture (service-based core, 3GPP Rel-15)

5G system = UE + NG-RAN (gNB) + 5G Core (5GC). The core uses a **service-based architecture**: network functions run as software (NFV) and talk over a common service bus, and control plane is separated from user plane (CUPS).

Function	Role
gNB	NR base station: radio transmission, scheduling, beamforming; may be split into CU and DU
AMF	Access and Mobility Management Function — registration, connection and mobility management, NAS signalling
SMF	Session Management Function — PDU session set-up, IP address allocation, selects and controls UPF
UPF	User Plane Function — routes and forwards user data packets, anchor for mobility, QoS enforcement, connects to data network

Advantages of 5G over 4G:

- Much higher data rate (up to 20 Gbps vs about 1 Gbps).
- Very low latency (1 ms vs 30–50 ms).
- Massive device connectivity ($10^6/\text{km}^2$) for IoT.
- Network slicing gives customised virtual networks.

(Diagram 2 M, functions 2 M, advantages 2 M)

b) MIMO and beamforming

6 M

MIMO (Multiple-Input Multiple-Output) uses multiple antennas at both transmitter and receiver. Using multipath propagation, it sends several independent data streams on the same frequency at the same time (spatial multiplexing) or the same data on several paths (diversity).

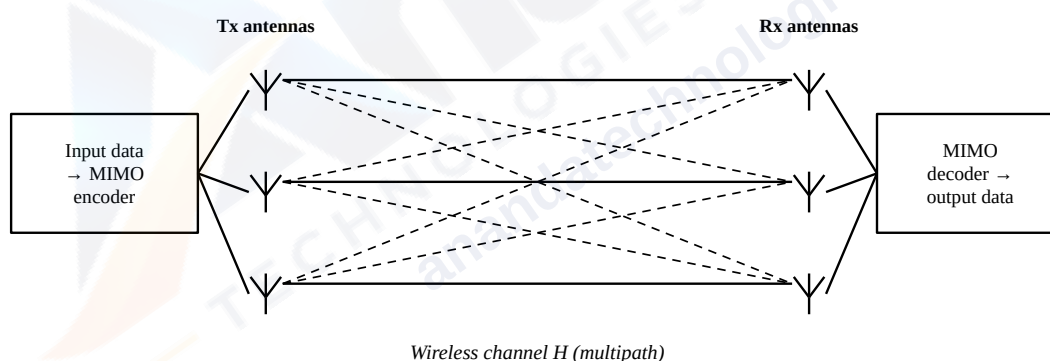


Fig.: MIMO system (N_t transmit and N_r receive antennas)

- Spatial multiplexing increases data rate/capacity ($\min(N_t, N_r)$ streams).
- Diversity improves reliability against fading.
- Used in Wi-Fi (802.11n/ac), LTE (up to 8×8) and 5G (massive MIMO).

Beamforming process: An antenna array (elements spaced about $\lambda/2$) feeds the same signal to every element with a controlled **progressive phase shift** and amplitude weight. In the desired direction the waves from all elements arrive in phase and add; in other directions they cancel. By changing the phase shifts electronically the beam is steered toward each user. The figure below is computed for an 8-element array.

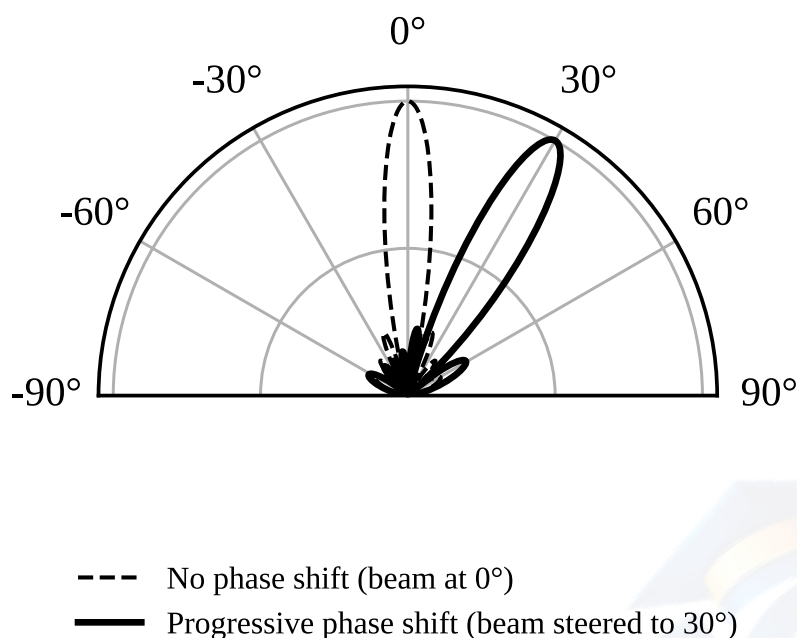


Fig.: Computed array pattern of a 8-element antenna array (spacing $\lambda/2$) — beamforming

Significance in 5G:

- Overcomes high path loss of mmWave bands by concentrating energy — extends coverage.
- Reduces interference to other users and cells; improves SINR.
- Enables multi-user MIMO — many users served on the same frequency with separate beams (higher capacity).
- Improves energy efficiency and supports beam tracking for moving users.

(MIMO with diagram 2 M, beamforming 2 M, significance 2 M)

c) Bluetooth piconet, scatternet and applications

6 M

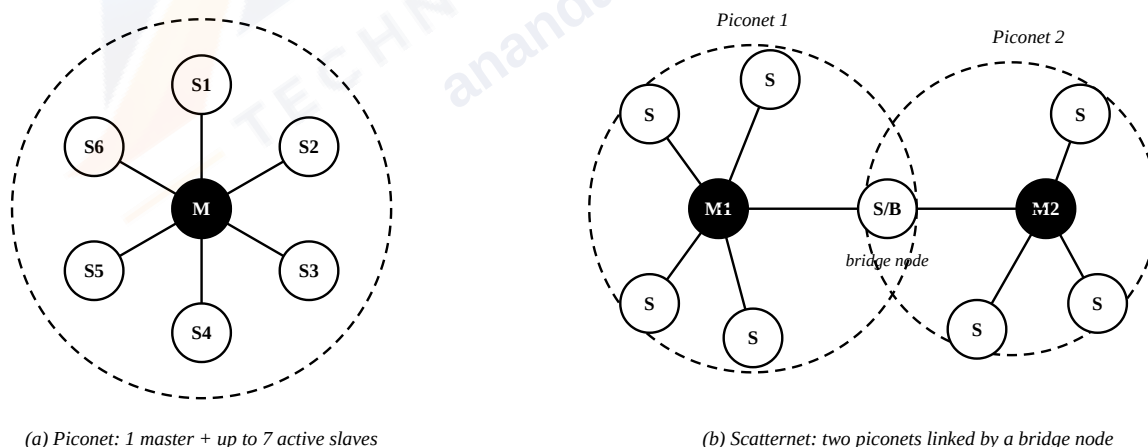


Fig.: Bluetooth piconet and scatternet

- **Piconet:** the basic Bluetooth network formed when devices connect ad hoc. One device acts as **master** (sets the clock and hopping sequence) and up to **7 active slaves** (and up to 255 parked slaves) synchronise to it. Slaves talk only through the master.

- **Scatternet:** two or more piconets interconnected. A device that is a member of two piconets (slave in both, or master in one and slave in the other) acts as a **bridge** and forwards data, so many devices can communicate beyond one piconet.

Applications of Bluetooth:

- Wireless headsets, earbuds and speakers
- File/photo transfer between phones and PCs
- Wireless keyboard, mouse, game controllers
- Car hands-free kits and infotainment
- Smart watches, fitness bands (BLE)

(Piconet 2 M, scatternet 2 M, applications 2 M)

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