# UNIT–4 : Cellular, Mobile and Wireless Technologies (PYQ Solution)

## PART–A Answers (≈70 Words Each)

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### Q1. What is the key principle behind Code Division Multiple Access (CDMA)? (2025)

**In CDMA, all users transmit at the same time on the same frequency band, but each user's data is multiplied by a unique spreading code (PN code) that spreads it over a wide bandwidth (spread spectrum).**

**The receiver multiplies by the same code to recover its user's data; other users' signals look like low-level noise. Codes are orthogonal (Walsh codes).**

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### Q2. Differentiate between GSM and CDMA telecommunication. (2022)

| GSM | CDMA |
|---|---|
| Uses **FDMA + TDMA** (8 time slots per 200 kHz carrier) | Uses **spread spectrum codes**, all share 1.25 MHz |
| Frequency reuse with clusters (N = 4/7) | Same frequency in every cell (reuse factor 1) |
| Hard handoff | **Soft handoff** |
| SIM card based | Originally handset based (R-UIM) |
| Worldwide (Europe, India) | USA, Korea (IS-95, CDMA2000) |

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### Q3. What is MTO? (2022)

**MTO / MTSO (Mobile Telephone Switching Office), also called the MSC, is the central switching centre of a cellular network.**

**It connects all cell sites (base stations) to each other and to the PSTN, assigns channels, handles call setup, handoff between cells, roaming, billing and keeps subscriber records. In AMPS it is called MTSO.**

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### Q4. Briefly explain the purpose of ZigBee technology. (2025)

**ZigBee (IEEE 802.15.4) is a low-power, low-data-rate, low-cost wireless standard for sensor and control networks.**

**It works at 2.4 GHz (250 kbps), range 10–100 m, battery life of years, and supports mesh networking with up to 65,000 nodes. Used in home automation (smart bulbs), industrial monitoring, smart meters and healthcare sensors.**

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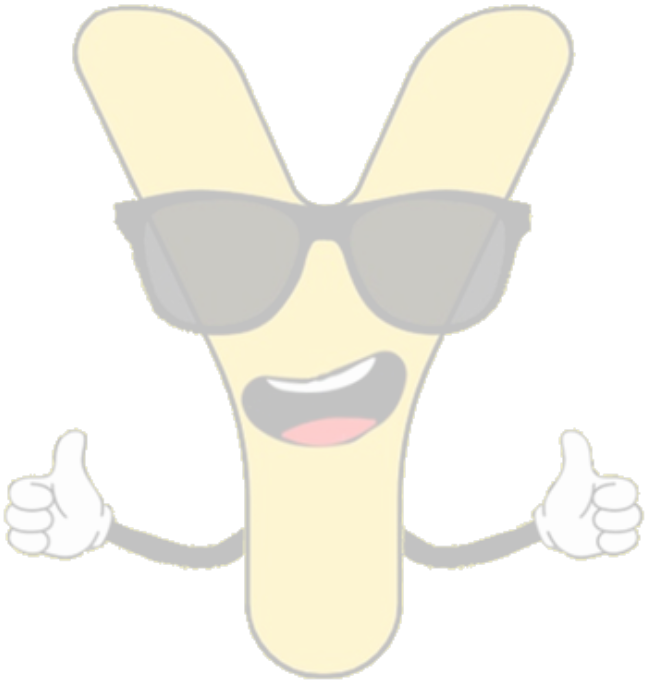
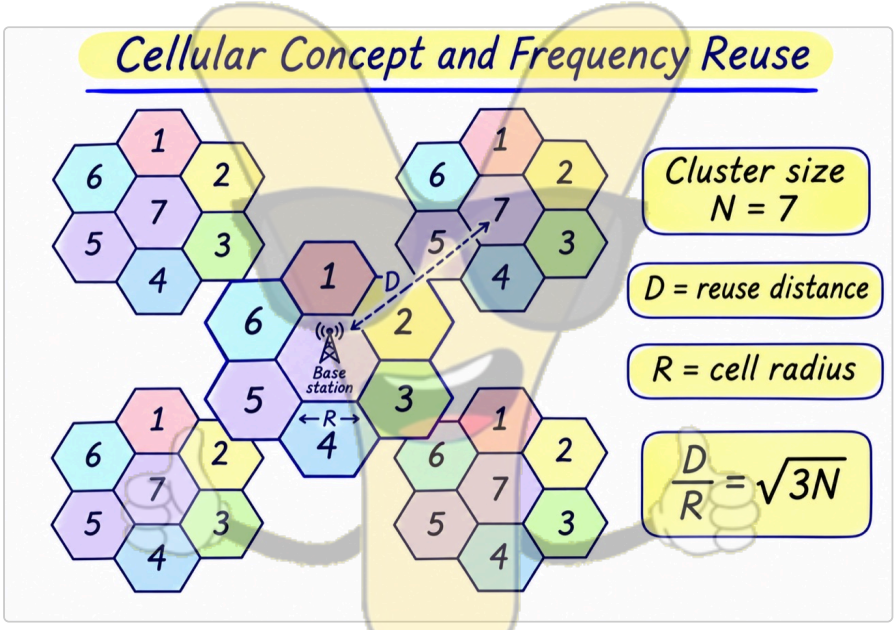


# PART–B Answers (≈250 Words Each)

### Q1. Explain the "cellular concept" in mobile communication and how it helps in frequency reuse. / Explain the frequency reuse concept in wireless communication. (2022, 2025)

**Problem:** the radio spectrum is limited. One big high-power tower for a whole city could serve only as many users as it has channels (a few hundred).

**Cellular concept:** divide the area into many small regions called **cells** (drawn as **hexagons**). Each cell has a low-power **base station** using only a part of the total channels. Because power is low, the same channels can be **reused** in another cell far enough away without interference.




**Frequency reuse:**

- Total channels S are divided among a group of **N cells called a cluster** (N = 3, 4, 7, 12). Each cell gets an equal share (k = S / N channels), and neighbouring cells always use different channel sets.
- The cluster pattern repeats over the whole area, so the same set of frequencies is used again and again.
- Cells using the same frequencies are **co-channel cells**. They must be kept a minimum distance apart, called the **reuse distance**, so their signals are too weak to disturb each other. A bigger cluster puts co-channel cells farther apart ($D = R\sqrt{3N}$, where R = cell radius); the ratio D/R is the **co-channel reuse ratio**.

- Only certain cluster sizes fit together without gaps in a hexagon pattern: 1, 3, 4, 7, 9, 12 … ($N = i^2 + ij + j^2$).

**Trade-off:** small N → more channels per cell (more capacity) but more co-channel interference; large N → less interference but less capacity.

**Example:** 700 channels, N = 7 → 100 channels per cell. If the city has 50 cells, capacity = 50 × 100 = 5000 simultaneous calls instead of 700.

**Handoff:** when a user moves to another cell, the call is switched to a new channel of that cell automatically.

**Benefits:** huge capacity from limited spectrum, low-power phones (longer battery life), easy growth by **cell splitting**.

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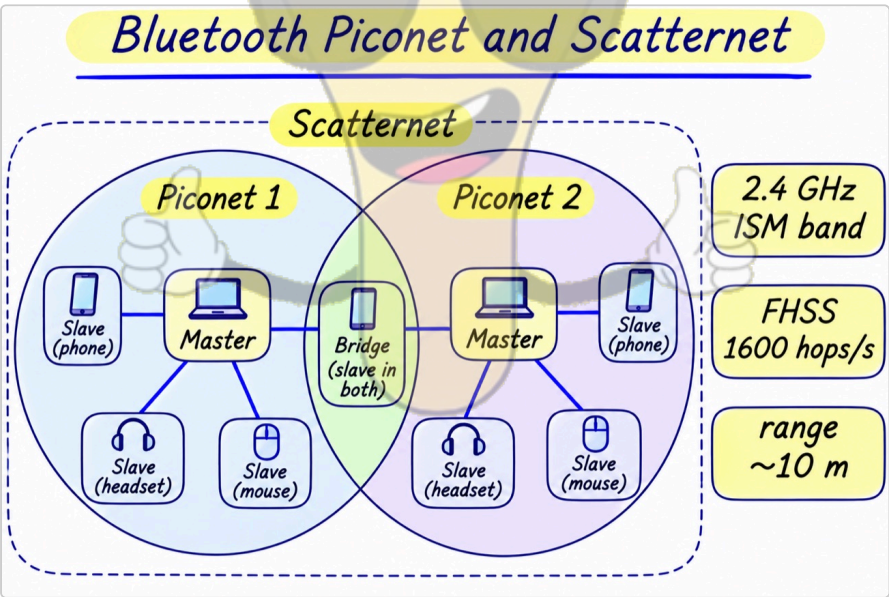
### Q2. Discuss the key features and applications of Bluetooth technology. (2025)

**Bluetooth (IEEE 802.15.1)** is a short-range wireless technology that replaces cables between personal devices — a **PAN (Personal Area Network)** technology.




**Key features:**

1. **Frequency:** 2.4 GHz ISM band (licence-free), 79 channels of 1 MHz.
2. **FHSS:** frequency hopping 1600 times per second — reduces interference and gives security.
3. **Range:** about 10 m (class 2); up to 100 m (class 1).
4. **Data rate:** 1 Mbps (basic), 3 Mbps (EDR), up to 2 Mbps for BLE 5.

5. **Piconet:** one **master** and up to **7 active slaves**; masters control timing (TDD).
6. **Scatternet:** two or more piconets joined through a common (bridge) device.
7. **Low power and low cost; Bluetooth Low Energy (BLE)** runs for months on a coin cell.
8. **Security:** pairing, authentication and encryption.
9. **Profiles:** A2DP (audio), HFP (hands-free), HID (keyboard/mouse), file transfer.

**Applications:** wireless earphones and speakers, hands-free car kits, keyboards and mice, file sharing between phones, smartwatches and fitness bands, medical sensors, IoT devices and tracking tags, game controllers.

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### Q3. Explain WiMAX and Metropolitan Area Networks. (Expected)

A **MAN (Metropolitan Area Network)** covers a **city** (5–50 km), linking many LANs. Examples: cable TV networks, city fiber rings, and wireless MAN.

**WiMAX (Worldwide Interoperability for Microwave Access)** is the **IEEE 802.16** wireless MAN standard for **broadband wireless access over long distances**.

**Features:**

- Range up to **50 km** (line of sight), 5–10 km typical non-line-of-sight.
- Data rate up to **70 Mbps** (shared), 1 Gbps in later version (802.16m).
- Frequencies 2–11 GHz (licensed and unlicensed).
- Uses **OFDM / OFDMA**, adaptive modulation (QPSK, 16-QAM, 64-QAM).
- **Fixed WiMAX (802.16d)** and **Mobile WiMAX (802.16e)**.
- Built-in **QoS** classes for voice and video.

**Architecture:** base station (tower) connects to the Internet backbone; subscriber stations (outdoor/indoor units) at homes and offices.

**Applications:** last-mile broadband in rural areas, backhaul for Wi-Fi hotspots and cell towers, enterprise connectivity.

WiMAX lost to **4G LTE** in mobile use, but its OFDMA idea is used in LTE.

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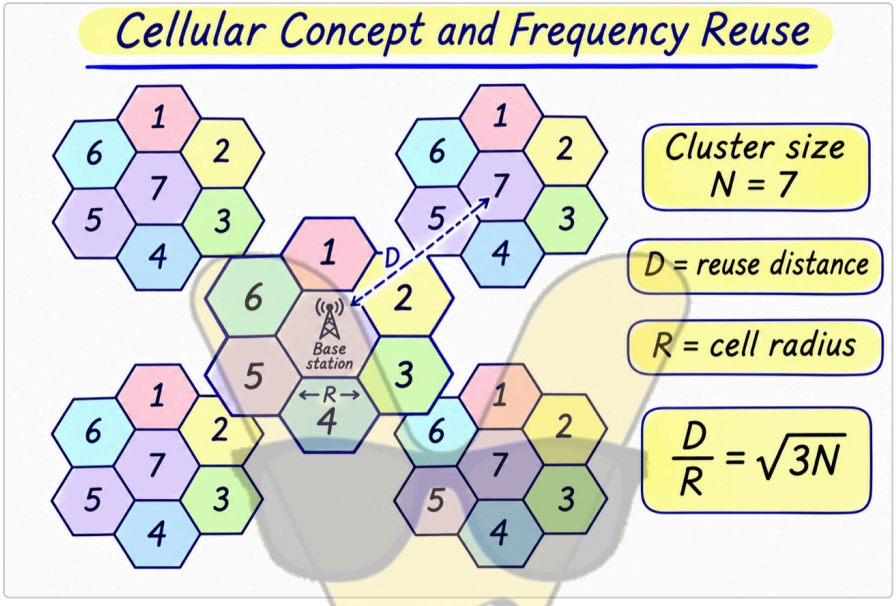
# PART–C Answers (≈500 Words Each)

### Q1. Explain in detail how can we improve the coverage and capacity in cellular system. (2022)

As the number of users grows, the system must carry more calls (**capacity**) and reach more places (**coverage**). Main techniques:




**1. Cell splitting:** a congested cell is divided into smaller cells, each with its own lower-power, lower-height base station. Same frequency plan is reused at a smaller scale. If radius becomes R/2, the number of cells — and capacity — becomes about **4 times**.

**2. Sectoring:** the omnidirectional antenna of a cell is replaced by **directional antennas** — 3 sectors of 120° or 6 sectors of 60°. Each sector receives interference from fewer co-channel cells, so **C/I improves** and a smaller cluster size N can be used → more channels per cell.

**3. Microcells, picocells and femtocells (small cells):** very small cells in busy places (malls, stations) and indoors. Improves both coverage (inside buildings) and capacity.

**4. Repeaters and range extenders:** re-broadcast signals into tunnels, basements and hilly areas — improves **coverage** (not capacity).

**5. Zone microcell concept:** a cell is divided into zones, each with a small antenna connected to one base station; the channel moves with the user between zones

without handoff — less interference and better coverage.

**6. Better channel allocation: dynamic channel allocation** and **channel borrowing** from lightly loaded neighbour cells.

**7. Better access and modulation techniques:** TDMA, **CDMA** (reuse factor 1), **OFDMA**, higher-order modulation (16/64-QAM), efficient voice codecs (half-rate).

**8. Smart antennas and MIMO:** beamforming focuses energy towards the user; multiple antennas carry parallel data streams.

**9. More spectrum and heterogeneous networks:** adding new bands, carrier aggregation, Wi-Fi offloading.

| Technique | Improves |
|---|---|
| Cell splitting | Capacity |
| Sectoring | Capacity (via lower interference) |
| Small cells | Capacity + coverage |
| Repeaters | Coverage |
| Zone microcell | Coverage + less interference |

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### Q2. Explain the AMPS and CDMA. (2022)

**AMPS (Advanced Mobile Phone System)** — the first-generation (**1G**) analog cellular system, launched by Bell Labs in the USA in **1983**.

**Features:**

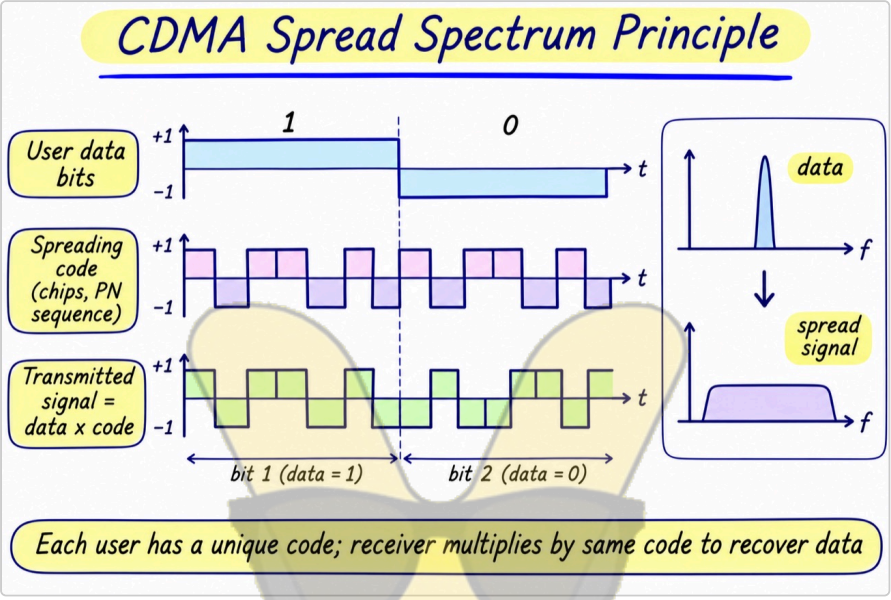
- **Analog FM** for voice; **FDMA** — each call uses one channel pair.
- Frequency band 824–849 MHz (uplink) and 869–894 MHz (downlink), **45 MHz** duplex spacing.
- Channel spacing **30 kHz**, 832 channels shared by two operators.
- Cluster size **N = 7**, cell radius 2–20 km.
- Control channels use 10 kbps FSK signalling.

**Architecture:** mobile unit → **cell site (base station)** → **MTSO** (switching office) → PSTN. The MTSO handles call setup and **handoff** when the user moves between cells.

**Call setup:** phone scans control channels, sends its ID (MIN/ESN), MTSO pages and assigns a voice channel, call proceeds on FM.

**Drawbacks:** low capacity, poor security (calls could be heard with scanners, phone cloning), no data services. Replaced by 2G digital (GSM, IS-136, CDMA).

**CDMA (Code Division Multiple Access)** — the **2G IS-95 / cdmaOne** system by Qualcomm, later CDMA2000 (3G).




**Principle:** every user transmits at the same time on the same 1.25 MHz carrier. Each user's data bit is multiplied by a fast **spreading code** (chips at 1.2288 Mcps). The receiver multiplies by the same code ("despreading"); the wanted signal comes back, other users stay spread like noise.

**Features:**

- **Frequency reuse factor 1** — every cell uses the same frequency.
- **Soft handoff:** phone connects to two base stations at once during handoff, so calls do not drop.
- **Power control** (800 times per second) solves the **near-far problem**.
- **RAKE receiver** combines multipath signals — turns fading into an advantage.
- Variable-rate vocoder, high security (codes are hard to detect).
- **Soft capacity:** more users can be added with slight drop in quality.

**AMPS vs CDMA:** analog vs digital, FDMA vs code division, hard vs soft handoff, low vs ~10× higher capacity.

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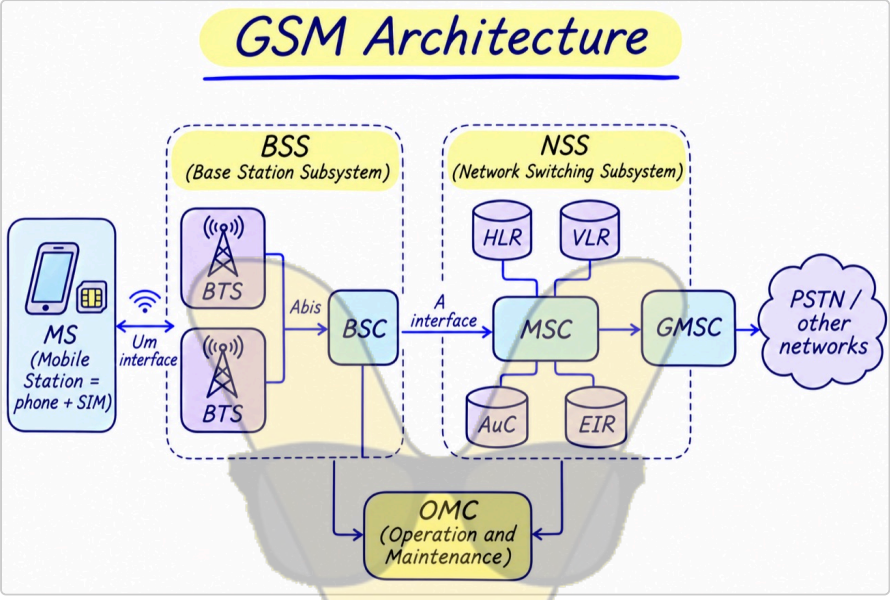
**Q3. (a) Compare and contrast GSM and CDMA cellular communication systems in terms of their multiple access techniques, security features and typical applications. (b) Explain the working principle and applications of RFID (Radio Frequency Identification) communication. (2025)**

**(a) GSM vs CDMA**

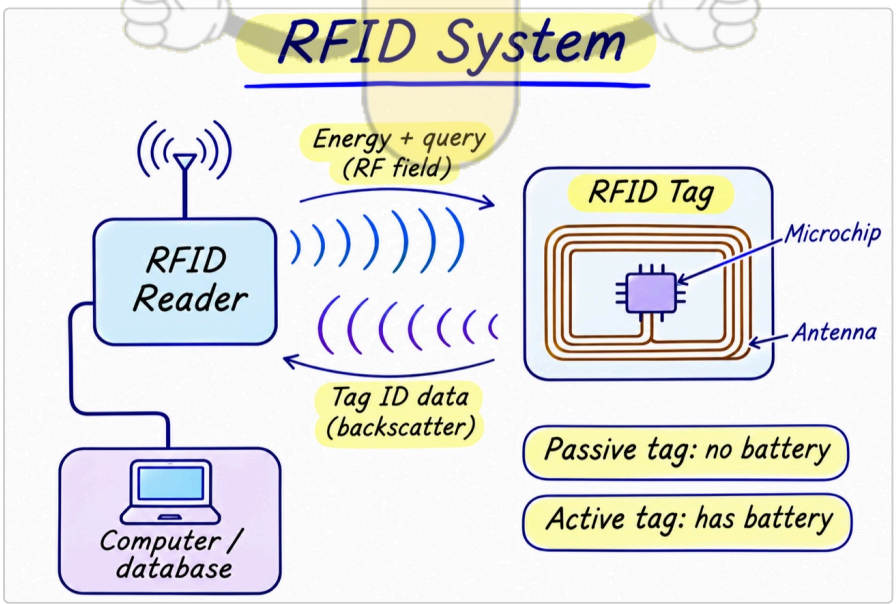



**GSM** (Global System for Mobile communication) is the 2G digital standard from Europe. Architecture: **MS** (phone + SIM) → **BTS** → **BSC** (together BSS) → **MSC** with databases **HLR**, **VLR**, **AuC**, **EIR** (NSS) → PSTN.

| Point | GSM | CDMA (IS-95) |
|---|---|---|
| **Multiple access** | FDMA + **TDMA**: 200 kHz carriers, each divided into 8 time slots | **Code division**: all users share 1.25 MHz at the same time with unique codes |
| Frequency reuse | Cluster of 4/7 cells | Reuse factor 1 |
| Handoff | Hard (break before make) | Soft (make before break) |
| Capacity | Fixed (hard limit by slots) | Soft capacity, higher |
| **Security** | **SIM** with secret key Ki; authentication by AuC (A3 algorithm), encryption A5/1 over air, TMSI hides identity | **Spread-spectrum codes** make signals hard to intercept; 42-bit long code mask; CAVE authentication |
| Identity | SIM card — easy to change phone | Handset-based ESN (later R-UIM) |
| Power control | Moderate | Very fast, essential |
| Data evolution | GPRS → EDGE → UMTS (WCDMA) | CDMA2000 1x → EV-DO |
| **Applications** | Worldwide voice, SMS, roaming; India (Airtel, Vodafone) | USA (Verizon, Sprint), Korea; India (Reliance, Tata Indicom in the past) |

**Summary:** GSM shares the channel by **time**, CDMA by **code**. GSM won worldwide because of the SIM and roaming; CDMA's ideas live on in 3G WCDMA.

**(b) RFID**




**RFID (Radio Frequency Identification)** identifies and tracks objects automatically using radio waves — no line of sight needed (unlike barcodes).

**Components:**

1. **Tag (transponder):** a microchip storing a unique ID plus an antenna coil. **Passive** tags have no battery; **active** tags have a battery and longer range.
2. **Reader (interrogator):** sends RF energy and receives tag data.
3. **Host computer / database:** processes the ID.

**Working principle:**

1. The reader sends an RF signal.
2. A passive tag's antenna picks up energy by **inductive coupling** (LF/HF) or **electromagnetic coupling** (UHF), which powers the chip.
3. The chip sends back its ID by **load modulation / backscatter** (changing how much energy it reflects).
4. The reader decodes the ID and passes it to the computer.

**Frequencies:** LF 125 kHz (few cm), HF 13.56 MHz (~1 m, NFC), UHF 860–960 MHz (several metres), microwave 2.45 GHz.

**Applications:** FASTag toll collection, supply chain and warehouse tracking, retail anti-theft, access cards, library books, animal tagging, passports, contactless payment (NFC).

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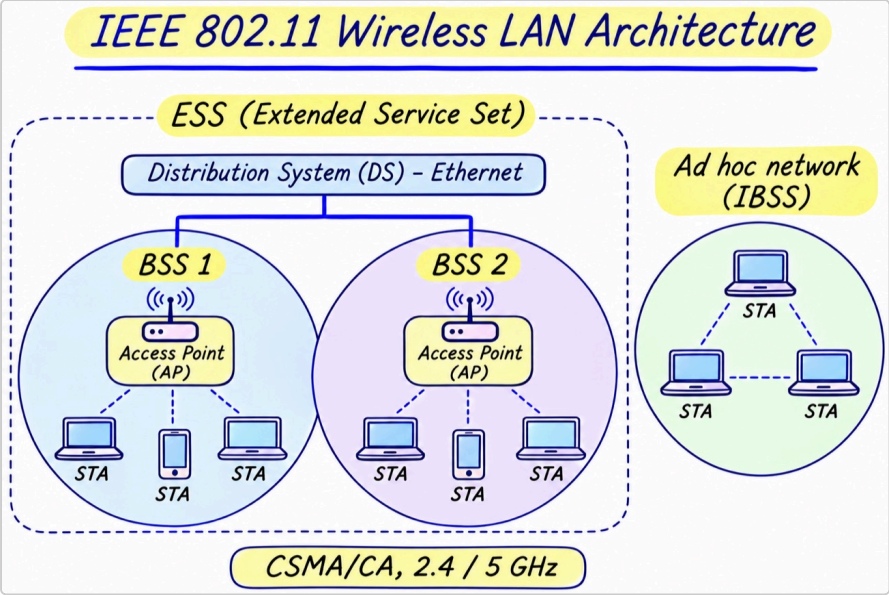
## Q4. (a) Describe the architecture and working of a Wireless LAN (WLAN) based on the IEEE 802.11 standard. (b) Discuss the advantages and disadvantages of Infrared Wireless communication compared to RF-based wireless technologies. (2025)

### (a) IEEE 802.11 WLAN (Wi-Fi)




**Architecture (components):**

1. **Station (STA):** any device with a wireless NIC (laptop, phone).
2. **Access Point (AP):** a base station that connects wireless stations to the wired network.
3. **BSS (Basic Service Set):** one AP with its stations — the basic cell.
4. **IBSS (ad hoc network):** stations talk directly without an AP.
5. **Distribution System (DS):** usually wired Ethernet connecting several APs.
6. **ESS (Extended Service Set):** many BSSs joined through the DS; looks like one network with one SSID; users can **roam** between APs.

**Layers:**

- **Physical layer:** 2.4 GHz and 5 GHz (6 GHz in Wi-Fi 6E) bands using DSSS, OFDM, MIMO. Versions: 802.11b (11 Mbps), a/g (54 Mbps), n (600 Mbps), ac (~Gbps), ax / Wi-Fi 6 (~9.6 Gbps).
- **MAC layer:** uses **CSMA/CA** (Collision Avoidance), because radios cannot detect collisions while transmitting.

**Working (CSMA/CA):**

1. A station senses the channel; if idle for a time **DIFS**, it waits a random back-off and then transmits.
2. The receiver replies with an **ACK** after a short gap (SIFS); no ACK → retransmit.
3. **RTS/CTS** (Request/Clear to Send) is used to solve the **hidden terminal problem**.
4. Stations join an AP by **scanning** (beacons), **authentication** and **association**.

5. Security by **WPA2/WPA3** encryption.

**(b) Infrared vs RF wireless**

**Infrared (IR) wireless** uses invisible light (850–950 nm) through LEDs/laser and photodiodes (IrDA, TV remotes, Li-Fi like systems).

**Advantages over RF:**

- **No licence** and no spectrum crowding; huge unregulated bandwidth.
- **High security** — IR cannot pass through walls, so data stays inside the room.
- **No RF interference** with other radios; safe near medical equipment and aircraft.
- Cheap, small, low-power components.
- Same frequency can be reused in every room.

**Disadvantages compared to RF:**

- Needs **line of sight** (or diffuse reflection); blocked by people, objects and walls.
- **Short range** (1–10 m).
- Strong **sunlight and lamps** create noise.
- Eye-safety limits on transmitted power.
- No mobility across rooms; RF (Wi-Fi, Bluetooth) covers wider areas through walls.

**Conclusion:** IR suits secure, short, point-to-point links; RF suits mobile, room-to-room networking.

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### Q5. Write a short note on UWB (Ultra Wideband). (2022)

**UWB (Ultra Wideband)** is a short-range radio technology that sends data using **very short pulses (nanoseconds)** spread over a **very wide bandwidth** — at least **500 MHz** or more than 20% of the centre frequency.

**Key points:**

- Frequency range **3.1 – 10.6 GHz** (FCC, 2002).
- **Very low power** density (−41.3 dBm/MHz) — it looks like background noise, so it can share spectrum with other systems without a licence.
- Uses **impulse radio** (pulse position/polarity) or **multiband OFDM**.
- **High data rate at short range:** 100–480 Mbps within ~10 m.
- **Precise ranging:** pulses are so short that time-of-flight gives distance to within ~10 cm.

- Resistant to **multipath fading**, because individual reflections can be separated in time.

**Advantages:** high speed, low power, low interference, accurate location, hard to intercept.

**Disadvantages:** very short range, interference concerns with other wideband systems, regulations differ by country.

**Applications:**

- **Precise indoor positioning** — Apple AirTag, Samsung SmartTag, phone "Find my" features.
- **Digital car keys** — the car knows exactly where the phone is.
- Wireless USB and HD video streaming (earlier).
- Ground-penetrating and through-wall **radar**, medical imaging.
- Asset tracking in factories and hospitals.

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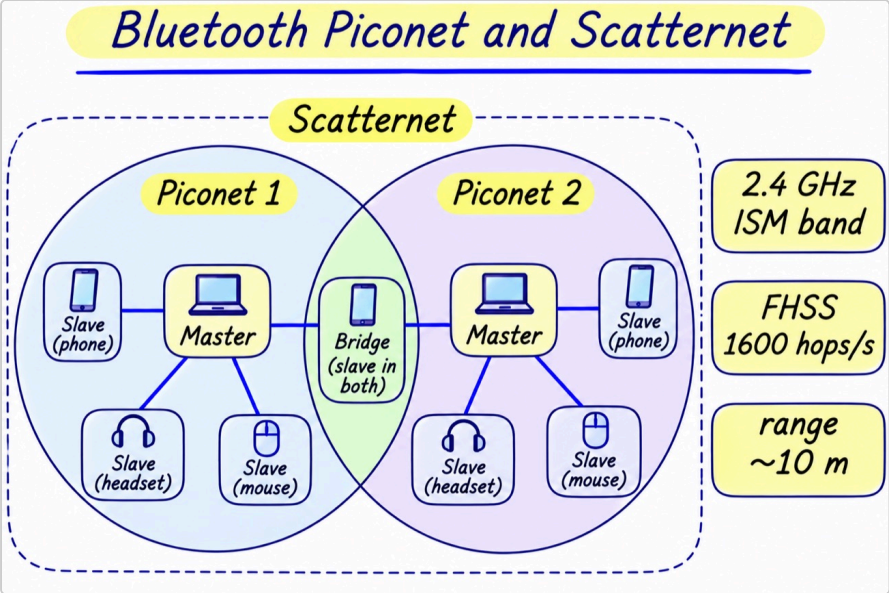
### Q6. Explain WCDMA and mesh wireless networks. (Expected)

**WCDMA (Wideband CDMA)** is the air interface of **3G UMTS**, the GSM family's third generation.

**Features:**

- **5 MHz** carrier (wideband) vs 1.25 MHz in CDMA IS-95; chip rate **3.84 Mcps**.
- **Direct-sequence spread spectrum** with OVSF codes for channels and scrambling codes for cells.
- Data rates 384 kbps (R99) → **14.4 Mbps with HSPA**, 42 Mbps HSPA+.
- **FDD mode** (paired bands, 1920–1980 / 2110–2170 MHz) and TDD mode.
- Fast power control (1500 Hz), **soft handover**, RAKE receivers.
- Supports voice, video calls and mobile Internet together.
- Network: UE → **Node B** → **RNC** → core network (MSC + SGSN/GGSN).

**Mesh wireless networks**




In a **wireless mesh network**, nodes connect directly and dynamically to as many other nodes as possible, and **relay data for each other** (multi-hop) instead of all going to one central AP.

**Parts:** mesh clients (laptops, sensors), mesh routers (relay nodes) and gateways (connect to the Internet).

**Features:**

- **Self-forming and self-healing:** if a node fails, traffic finds another path.
- Wide coverage without wiring each node.
- Easy expansion — just add nodes.

**Examples:** Wi-Fi mesh systems (Google Nest Wifi, Deco), **ZigBee** and Thread smart-home networks, Bluetooth Mesh, city-wide and disaster-recovery networks.

**Disadvantages:** more hops add delay and reduce throughput; routing is complex.

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