✅ **MODULE 3 – Wireless Technologies**

- Bluetooth, ZigBee, Mesh
- NFC & RFID
- Ultrawideband & Extra Wireless Apps
- WiMAX & WMAN + Infrared Wireless + RF
- Wireless LAN + PANs

✅ **MODULE 4 – Optical Communication**

- Optical principles
- Optical communication systems
- Fiber-optic cables
- Optical transmitters & receivers
- WDM
- Passive optical networks
- 40/100 Gbps networks

✅ **MODULE 5 – Satellite Communication**

- Satellite Orbits
- Satellite Communication Systems
- Satellite Subsystems
- Ground Stations
- Satellite Applications
- GNSS (Global Navigation Satellite Systems)

📘 MODULE 3 — WIRELESS TECHNOLOGIES

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1. Wireless LAN (Wi-Fi)

A Wireless LAN allows devices to connect to a network through radio waves instead of cables.

Key points

- Based on **IEEE 802.11 standards**
- Common names: **Wi-Fi / WLAN**
- Used in homes, offices, airports, cafés
- Devices: **Access Point (AP), Wireless Router, Radio Modems**

Architectures

1. **Infrastructure mode**
    - AP connects wireless devices to wired LAN backbone
2. **Hotspot**
    - AP connected to ISP for public Wi-Fi
3. **Home WLAN**
    - Router acts as modem + AP (NAT enabled)

Wi-Fi Standards

- **802.11b** → 11 Mbps, 2.4 GHz, DSSS
- **802.11a** → 54 Mbps, 5 GHz, OFDM
- **802.11g** → 54 Mbps, 2.4 GHz, backward compatible with b
- **802.11n** → 100–600 Mbps, MIMO, dual-band

Related Standards

- 11e (QoS)
- 11i (Security: WEP, WPA, WPA2)
- 11s (Mesh)
- 11u (Handoff, roaming)
- 11p (Vehicle-to-vehicle DSRC — cars)

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2. PANs and Bluetooth

A PAN is a short-range personal network (few meters).

Bluetooth basics

- Operates in **2.4 GHz ISM band**
- Uses **FHSS (1600 hops/sec)**
- Data rate: **1 Mbps (classic), 3 Mbps (EDR)**
- Devices auto-connect using inquiry/scan signals

Network structures

- **Piconet** → 1 master + up to 7 slaves
- **Scatternet** → multiple interconnected piconets

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3. ZigBee and Mesh Wireless

Based on **IEEE 802.15.4**, designed for low-power devices.

Key points

- Used in IoT, home automation, sensors
- Low data rate (20–250 kbps)
- Long battery life, low power
- Uses license-free ISM bands

Network Topologies

- **Star** (central controller)
- **Mesh** (multi-hop routing)
- **Cluster tree**

Node Types

- **ZC:** Coordinator (one per network)
- **ZR:** Router (forwarding)
- **ZED:** End device (no forwarding)

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4. WiMAX and Wireless MAN

WiMAX = **Worldwide Interoperability for Microwave Access**

Standard

IEEE **802.16**, meant for **broadband wireless MANs**

Applications

- Wireless broadband to homes/business
- Backhaul links (cell towers, hotspots)

Modes

- **Point-to-Point (P2P)** → backhaul
- **Point-to-Multipoint (PMP)** → last-mile broadband

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5. Infrared Wireless

Basics

- Uses **IR light**
- Requires **line-of-sight**
- Common in **TV remotes**

Remote Control System

- IR LED transmitter sends coded pulses
- Receiver uses photodiode + amplifier + decoder
- Uses **Manchester / biphase coding**

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6. RFID & NFC

RFID

- Wireless identification using **tags**
- Passive tags → no battery
- Used in inventory, tolls, tracking

NFC

- Very short-range, derived from RFID
- Used in payments, ID cards, tap-and-go systems

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7. Ultrawideband (UWB)

- Very low power, very wide frequency spectrum
- Used in radar, indoor localization
- High accuracy positioning

✅ 2-MARK QUESTIONS — Module 3

1. Define Wireless LAN.

A Wireless LAN (WLAN) is a local-area network that uses radio communication instead of cables, based on IEEE 802.11 standards, allowing devices to connect to network services through wireless access points.

2. What is a PAN?

A Personal Area Network (PAN) is a small, informal wireless network connecting devices over a short range (few meters), commonly implemented using Bluetooth.

3. What is Bluetooth?

Bluetooth is a digital wireless standard using **FHSS** in the **2.4 GHz ISM band**, transmitting data at 1–3 Mbps and supporting short-range PAN networks.

4. What is a piconet?

A piconet is a small Bluetooth network with **1 master** device and up to **7 slave** devices connected.

5. What is ZigBee?

ZigBee is a low-power, low-cost wireless technology based on **IEEE 802.15.4**, designed for monitoring and control applications (IoT, home automation).

6. What are ZigBee node types?

- ZC: Coordinator
- ZR: Router
- ZED: End Device

7. What is WiMAX?

WiMAX is a wireless broadband technology based on IEEE **802.16**, used for MAN (Metropolitan-Area Network) connectivity, supporting P2P and PMP modes.

8. Define Infrared Wireless.

Infrared wireless uses IR light for short-distance, line-of-sight communication, commonly used in TV remotes.

9. What is RFID?

RFID is a technique using tags with passive radio circuits that can be wirelessly identified and tracked by a reader.

10. What is NFC?

NFC (Near-Field Communication) is a very short-range wireless communication method derived from RFID, used in contactless payments and access systems.

11. What is Ultrawideband (UWB)?

UWB is a wireless technology that uses extremely wide bandwidth and low power, enabling high-precision indoor positioning.

12. What is an Access Point (AP)?

An AP is a transceiver device that connects wireless devices to a wired network or the internet.

✅ 5-MARK QUESTIONS — Module 3

1. Explain the architecture and working of a Wireless LAN.

A WLAN uses APs connected to existing wired networks (Ethernet). Three configurations exist: enterprise APs, public hotspots, and home wireless routers. APs contain radio transceivers covering ~100 m. Wireless devices associate with APs to access LAN or Internet resources.

2. Compare Bluetooth and ZigBee.

Feature	Bluetooth	ZigBee
Standard	Proprietary (FHSS), IEEE adaptations	IEEE 802.15.4
Range	Short	Short–medium
Data Rate	1–3 Mbps	20–250 kbps
Focus	Cable replacement	Control applications
Network Types	Piconet / Scatternet	Star, Mesh, Cluster tree

3. Explain Bluetooth piconet and scatternet with diagram.

- **Piconet**: One master, up to 7 slaves
- **Scatternet**: Multiple piconets connected; one device may act as slave in one and master in another Hopping sequence of master controls entire piconet.

4. Explain ZigBee network architecture and topologies.

ZigBee supports star, mesh, and cluster-tree structures. ZC initializes network; ZR forwards packets; ZED acts as low-power end device. Mesh topology offers reliability via multiple paths.

5. Explain WiMAX and its applications.

WiMAX supports long-range broadband access. **802.16d** standard. Works in P2P and PMP modes. Applications include broadband last-mile access, backhaul for cell towers, hotspot connections, and rural broadband.

6. Explain IR remote control system.

A transmitter uses an IR LED modulated using Manchester/biphase coding. A keyboard matrix generates serial binary codes. Receiver uses photodiode + AGC amplifier + decoder microcontroller to control devices.

✅ 10-MARK QUESTIONS — Module 3

1. Describe all IEEE 802.11 WLAN standards in detail.

Include:

- 802.11b: 2.4 GHz, DSSS, 11 Mbps
- 802.11a: 5 GHz, OFDM, 54 Mbps
- 802.11g: 2.4 GHz, OFDM, 54 Mbps
- 802.11n: MIMO, dual band, 600 Mbps
- Related standards: 11e (QoS), 11i (Security), 11s (Mesh), 11u (Handoff), 11p (Vehicle-to-vehicle)

2. Explain ZigBee in detail: architecture, node types, OSI layers, topologies, applications.

Cover: ZC/ZR/ZED roles, 802.15.4 PHY/MAC, mesh/star/tree networks, ISM bands, industrial automation examples.

3. Explain WiMAX architecture, operation, standards, and applications.

Cover P2P, PMP, channel structure, frequency bands, use in broadband MAN.

4. Explain RFID and NFC in detail with diagrams.

Include: passive tags, active tags, interrogation unit, reader→tag→reader communication, NFC use cases.

📘 MODULE 4 — OPTICAL COMMUNICATION

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1. Optical Principles

Reflection

Angle of incidence = angle of reflection.

Refraction

Light bends when speed changes between two media.

Total Internal Reflection (TIR)

Occurs when:

- Light travels from high → low refractive index
- Angle > critical angle
  This principle enables **fiber-optic transmission**.

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2. Fiber-Optic Cables

Construction

- **Core** (glass/plastic, high refractive index)
- **Cladding** (lower refractive index)
- **Jacket** (protection)

Types of fibers

1. **Step-Index Multimode**
    - Large core (50–1000 µm)
    - High modal dispersion
    - Low-cost, short distance
2. **Graded-Index Multimode**
    - Refractive index decreases from center → edge
    - Lower dispersion
3. **Single-Mode**
    - Very small core (2–15 µm)
    - No modal dispersion
    - Long-distance, high bandwidth
    - Requires lasers

Numerical Aperture (NA)

Determines acceptance angle for light entry.

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3. Optical Communication Systems

Components

- **Light source:** LED / Laser
- **Modulator:** OOK / ASK / Analog intensity modulation
- **Fiber channel**
- **Detector:** Photodiode
- **Amplifier & decoder**

Free-Space optical communication

Uses light (Lasers/LEDs) through atmosphere → affected by fog, dust.

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4. Dispersion

- **Modal dispersion** (multimode)
- **Chromatic dispersion** (multiple wavelengths)
- **Polarization mode dispersion (PMD)** (single mode)

All dispersion leads to **pulse spreading → limits data rate**.

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5. Wavelength Division Multiplexing (WDM)

- Multiple light wavelengths (λ1, λ2...) transmitted in single fiber
- Two types:
    - **CWDM** (coarse)
    - **DWDM** (dense)
- Enables **40/100 Gbps and beyond**

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6. Passive Optical Networks (PON)

- Fiber to home (FTTH) systems
- Passive splitters distribute signals
- Types: **GPON, EPON**

✅ 2-MARK QUESTIONS — Module 4

1. What is total internal reflection?

When light moves from higher to lower refractive index and angle of incidence exceeds critical angle, it reflects entirely inside the medium.

2. Define numerical aperture (NA).

NA defines the acceptance angle of a fiber and determines how much light it can collect.

3. What is a fiber-optic cable?

A thin strand of glass/plastic that carries light using total internal reflection.

4. What is the difference between LED and laser?

LED emits incoherent light; laser emits coherent, monochromatic, narrow beam with higher data rates.

5. What is dispersion?

Stretching of optical pulses due to different propagation speeds. Types: modal, chromatic, PMD.

6. What is WDM?

Technique of multiplexing multiple wavelengths (λ1, λ2…) on a single fiber to increase bandwidth.

7. What is a PON?

A Passive Optical Network uses passive splitters to deliver fiber-optic internet (e.g., GPON).

8. What is attenuation?

Loss of optical signal strength caused by absorption, scattering, and dispersion.

✅ 5-MARK QUESTIONS — Module 4

1. Explain fiber-optic cable construction.

Layers:

- Core
- Cladding
- Jacket
- Strength members
  Cladding has lower refractive index than core. Total internal reflection propagates signal.

2. Explain step-index and graded-index fibers.

- **Step-index**: abrupt refractive index change at core–cladding boundary
- **Graded-index**: refractive index decreases gradually outward

3. Explain multimode vs single-mode fiber.

MM: many modes, more dispersion, larger core
SM: one mode, negligible dispersion, long-distance, expensive

4. Explain optical communication system block diagram.

Source → Modulator → Fiber → Detector → Amplifier → Decoder
Cover PCM pulses, OOK, photodiodes.

5. Explain free-space optical communication.

Light travels through open air using lasers/LEDs; atmospheric effects cause attenuation.

✅ **10-MARK QUESTIONS — Module 4**

1. Explain the principles of optics (reflection, refraction, critical angle, TIR) with diagrams.

2. Explain all types of optical fibers, dispersion types, properties, bandwidth, and specifications.

3. Explain WDM in detail, types (CWDM, DWDM), components and advantages.

4. Explain optical transmitters (LED/Laser) and receivers (photodiodes) in detail.

📘 MODULE 5 — SATELLITE COMMUNICATION

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1. Satellite Orbits

Orbit types

- **LEO** (400–1000 mi) → low delay (10 ms)
- **MEO** (1000–6000 mi) → medium delay (100 ms)
- **GEO** (22,300 mi; 35,888 km) → 24-hr orbit, fixed location

Orbit parameters

- Apogee (farthest)
- Perigee (closest)
- Inclination
- Azimuth & elevation
- Latitude & longitude

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2. Satellite Communication System

Uplink / Downlink

- Uplink → Earth → Satellite
- Downlink → Satellite → Earth

Transponder

- Receives signal
- Amplifies
- Frequency translation
- Re-transmits

Used frequencies:

- **C-band**: 6/4 GHz
- **Ku-band**: 14/12 GHz
- **Ka-band**: higher frequency, higher data rates

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3. Satellite Subsystems

Communication subsystem

- Multiple transponders

Telemetry, Tracking & Command (TT&C)

- Monitors satellite health
- Controls satellite functions

Antenna subsystem

- Parabolic reflector
- Diplexer for Tx/Rx separation

Propulsion subsystem

- Jet thrusters
- Apogee kick motor (AKM)

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4. Ground Stations

Subcomponents

- Antenna (large parabolic dish)
- Receive subsystem (LNA, down-converters)
- Transmit subsystem (up-converters, power amplifiers)
- Ground Control Equipment (demodulation, decoding)

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5. Satellite Applications

- TV broadcasting
- Weather forecasting
- GPS
- Mobile communication
- Internet services
- Navigation systems

✅ 2-MARK QUESTIONS — Module 5

1. Define a satellite.

A satellite is an object that orbits a celestial body, maintained by balance between inertia and gravity.

2. What is an uplink and downlink?

Uplink: Earth → Satellite (e.g., 6 GHz)
Downlink: Satellite → Earth (e.g., 4 GHz)

3. What is a transponder?

A satellite unit that receives, amplifies, frequency-translates, and retransmits signals.

4. What is GEO?

A geostationary orbit at 22,300 miles where satellite appears fixed relative to Earth.

5. What is TT&C?

Telemetry, Tracking, and Command subsystem monitors satellite health and issues control commands.

6. What is a ground station?

Earth-based facility with antenna, receiver, transmitter, and control equipment communicating with satellite.

7. Define apogee and perigee.

Apogee = farthest point in orbit.
Perigee = closest point in orbit.

✅ 5-MARK QUESTIONS — Module 5

1. Explain satellite orbits and their types.

Include: LEO, MEO, GEO, inclination, azimuth, elevation.

2. Explain the working of a communication satellite with block diagram.

Include: uplink, transponder operations, downlink.

3. Explain frequency bands used in satellite communication.

C-band (6/4 GHz), Ku-band (14/12 GHz), Ka-band advantages.

4. Explain satellite subsystems.

- Communication subsystem
- TT&C
- Propulsion subsystem
- Antenna subsystem

5. Explain the components of a ground station.

Antenna, diplexer, LNA, down converters, up converters, high-power amplifiers, control equipment.

✅ **10-MARK QUESTIONS — Module 5**

1. Describe in detail: GEO satellites, orbital parameters, advantages, applications.

2. Explain satellite communication system with diagrams — uplink, downlink, transponders.

3. Explain all satellite subsystems (TT&C, propulsion, communication, antennas).

4. Explain ground station in detail — transmitter, receiver, frequency conversion, equipment racks.

✅ 1) Differences between Bluetooth and ZigBee technologies

(Based on *Module 3 – Wireless Technologies*)

Feature	Bluetooth	ZigBee
Standard	Digital radio using **FHSS** in 2.4 GHz ISM band	Based on **IEEE 802.15.4**
Purpose	Cable replacement, audio devices, short-range PANs	Monitoring & control, IoT applications
Data Rate	**1 Mbps** (Classic), **3 Mbps** (EDR)	**20–250 kbps**
Range	Short-range personal connectivity	Short-to-medium range sensing/control
Network Type	**Piconet** (1 master + 7 slaves), **Scatternet**	**Star, Mesh, Cluster-tree**
Power Consumption	Higher than ZigBee	Very low power, long battery life
Applications	Headsets, phones, file transfer	Smart homes, automation, sensors

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✅ 2) Explain the concept of Wavelength Division Multiplexing (WDM)

unit4

Wavelength Division Multiplexing is a technique that **allows multiple light signals with different wavelengths** (colors) to be transmitted **simultaneously through a single optical fiber**.
Each wavelength carries an independent data channel.

Key Points from the PDF:

- Greatly increases the **bandwidth capacity** of a fiber.
- Used in **40/100 Gbps networks and beyond**.
- Forms the basis of **DWDM** (dense WDM) and **CWDM** (coarse WDM).
- Enables long-distance high-speed communication without requiring more fibers.

✅ 3) Explain the concept of total internal reflection in optical fibers

Total internal reflection (TIR) occurs when:

1. Light travels from a medium of **higher refractive index** (fiber core)
2. To a **lower refractive index** medium (cladding)
3. And **angle of incidence exceeds the critical angle**

When this happens, **light does not pass into the cladding** — instead, it reflects **entirely inside the core**, travelling down the fiber.

As per the PDF:

- TIR is the **basic principle that allows a fiber-optic cable to work**.
- Only rays entering at angles **greater than the critical angle** undergo continuous reflection.
- This keeps the light trapped inside the core and enables long-distance transmission.

✅ 4) Draw and explain the general block diagram of an Earth Station

(Based on *Ground Stations – Module 5*)

Earth Station Block Diagram Components:

1. **Antenna Subsystem**
    - Large **parabolic dish**
    - Uses a **diplexer** to allow same antenna for Tx/Rx
2. **Receive Subsystem (Downlink)**
    - **LNA (Low Noise Amplifier)**
    - **Down-converters**
    - Feed to Ground Control Equipment
3. **Ground Control Equipment (GCE)**
    - Demodulates & demultiplexes received signals
4. **Transmit Subsystem (Uplink)**
    - **Up-converters**
    - **High-power amplifiers**
    - Feed signal to antenna

These subsystems work together to receive data from the satellite and send data back to it.

✅ 5) What is GNSS? Explain the segments present in GNSS

GNSS (Global Navigation Satellite System) is a satellite-based navigation system that provides **positioning, navigation, and timing** information worldwide.

Segments of GNSS:

1. **Space Segment**
    - Constellation of navigation satellites
    - Continuously broadcast timing and positioning signals
2. **Control Segment**
    - Ground stations monitoring satellite health
    - Sends corrections and updates to satellites
3. **User Segment**
    - GNSS receivers (phones, vehicles, ships)
    - Calculate position using signals from multiple satellites

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✅ 6) Explain the architecture and components of a Wireless LAN and WiMAX

A) Wireless LAN (WLAN) Architecture

Components

- **Access Point (AP)** — connects wireless devices to wired LAN
- **Wireless Router** — used in homes, handles NAT
- **Wireless Modems / Radio Modems** — in PCs/laptops

Architectures

1. **Enterprise WLAN**
    - AP connected to Ethernet switches
2. **Public Hotspot**
    - AP connected to ISP
    - Airports, hotels, cafes
3. **Home Network**
    - Residential gateway → DSL/Cable modem → Wi-Fi devices

B) WiMAX Architecture (Wireless MAN)

Standard

IEEE **802.16**

Components

- **Base Station** → Provides wireless broadband
- **Subscriber Stations** → Customer-end devices
- **Backhaul Connections** → Connects base station to ISP

Modes

1. **Point-to-Point (P2P)**
    - Backhauling cell towers, hotspots
2. **Point-to-Multipoint (PMP)**
    - Broadband service to homes/businesses

Applications

- Wireless broadband
- Rural internet
- Enterprise connectivity
- Hotspot backhaul
- Cable/DSL alternative

✅ **7) Differentiate between GEO, MEO, and LEO satellites**

Feature	LEO	MEO	GEO
Altitude	400–1000 miles	1000–6000 miles	22,300 miles
Delay	~10 ms (low)	~100 ms (medium)	~250–300 ms
Coverage Area	Small	Medium	Very large
Satellite Speed	Very fast (17,500 mi/h)	Moderate	Slow (appears stationary)
Uses	Imaging, LEO constellations	GPS, navigation	TV broadcasting, communication

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✅ 8) Explain the architecture of RFID

RFID consists of two main elements:

1. RFID Tag

- Thin passive circuit
- Contains **antenna** + **chip with memory**
- Stores unique ID code
- Powered by the reader's signal (passive tags)

2. Interrogator / Reader

- Sends radio signal to activate the tag
- Receives backscattered response
- Processes ID information

Working Principle

1. Reader emits RF signal
2. Passive tag harvests power
3. Tag sends stored ID back
4. Reader decodes information

Applications

- Inventory control
- Toll collection
- Baggage tracking
- Access control
- Theft prevention

✅ 9) Explain how Infrared Wireless Communication is used in short-range devices

Infrared wireless uses **IR light** to transmit data across short distances.

How it works

- A **handheld transmitter** uses an **IR LED** to send **digital serial codes**
- Codes are modulated using **Manchester or biphase encoding**
- The **receiver** (TV, DVD, etc.) has:
    - **Photodiode sensor**
    - **High-gain amplifiers**
    - **AGC circuitry**
    - **Decoder microcontroller**

Requirements

- **Line-of-sight** communication
- Does **not** penetrate walls
- Limited to short distances (typically 6–15 feet)

Examples

- TV remote controls
- Air conditioner remotes
- Audio system remotes

 # Module 3 — Wireless Technologies

(Reference: unit3.pdf).

unit3

Bluetooth

Definition & purpose
Bluetooth is a short-range wireless PAN technology intended originally as a cable-replacement (headsets, phone-headset links). It operates in the unlicensed 2.4 GHz ISM band using Frequency-Hopping Spread Spectrum (FHSS).

unit3

How it works (essentials)

- **Hop set:** 79 channels (2.402–2.480 GHz), hop rate ≈ 1600 hops/s.
- **Data rates:** Classic ~1 Mbps (useful payload ≈ 723.2 kbps simplex), Enhanced Data Rate (EDR) up to 3 Mbps.
- **Network structure:** *Piconet* — one master + up to 7 active slaves; multiple piconets can interconnect to form a *scatternet*.
- **Typical exam diagram:** draw a master node with arrows to up to 7 slave nodes (label master/slave, hop sequence).

unit3

Key points to memorise

- FHSS, 2.4 GHz ISM, piconet/scatternet, EDR = 3 Mbps.

unit3

Exam tips

- 2-mark: define Bluetooth / piconet.
- 5-mark: explain piconet + scatternet and hop mechanism.
- 10-mark: compare Bluetooth vs Wi-Fi/ZigBee (use table).

ZigBee & Mesh Wireless Networks

Definition & purpose
ZigBee is a low-power, low-data-rate wireless standard built on IEEE **802.15.4** for control/monitoring (IoT, sensors, automation). Mesh networking and low energy are the main features.

unit3

Architecture & operation

- **PHY/MAC:** defined by 802.15.4 (physical + MAC).

- **Node types:** ZC (ZigBee Coordinator — network starter), ZR (Router — forwards traffic), ZED (End Device — low power, no routing).
- **Topologies:** star, mesh, cluster tree — *mesh* provides multi-hop reliability (diagram: coordinator ↔ routers ↔ end devices).

unit3

Key points

- Low power, operates in ISM bands, designed for battery-operated sensors, supports star/mesh/cluster tree.

unit3

Exam tips

- 2-mark: name node types.
- 5-mark: draw mesh topology and explain routing advantage.
- 10-mark: full architecture with OSI mapping (PHY/MAC from 802.15.4 + ZigBee application layers).

NFC & RFID

Definitions

- **RFID:** Radio-Frequency ID — tags (passive/active) + readers; used for inventory, tolls, baggage.
- **NFC:** Near-Field Communication — very short range (tap-to-pay) derived from RFID concepts.

unit3

Architecture & working

- **Tag:** antenna + chip with ID memory (passive tags harvest reader power).
- **Reader/interrogator:** transmits RF → tag backscatters/reflects ID → reader decodes.
- **Exam diagram:** reader → interrogator field → passive tag (label antenna/chip).

unit3

Key facts

- RFID = inventory, toll collection; NFC = proximity services (payments).

unit3

Exam tips

- 2-mark: define RFID or NFC.
- 5-mark: sketch and explain passive tag operation.
- 10-mark: compare active vs passive tags, list applications and limitations.

Ultrawideband (UWB) & Additional Wireless Applications

Essentials

- **UWB:** uses extremely wide frequency bands at very low power — excellent for precise indoor ranging/positioning and short-range high-precision radar.
- **Other apps:** IoT, M2M (machine-to-machine), home automation, vehicular communications (802.11p for V2X mentioned as related).

unit3

Exam tips

- 2-mark: define UWB.
- 5-mark: explain UWB use in indoor localization and radar basics.

WiMAX & Wireless Metropolitan-Area Networks (WMAN)

Definition & purpose
WiMAX (IEEE 802.16) is a wireless MAN technology intended to provide broadband wireless access (last-mile, backhaul). It offers both P2P and PMP modes.

unit3

Architecture & operation

- **802.16d/802.16e** variants for fixed/mobile.
- **Modes:** P2P (point-to-point backhaul) and PMP (point-to-multipoint for subscriber access).
- **Exam diagram:** base station ↔ subscriber stations; note backhaul to ISP.

unit3

Key facts

- Competes with DSL/cable for broadband; used in rural and hotspot backhaul.

unit3

Exam tips

- 5-mark: list uses and explain P2P vs PMP.
- 10-mark: architecture, MAC/PHY highlights, advantages vs wired.

Infrared Wireless

Definition & operation
Infrared (IR) wireless uses light (not RF) for short-distance, line-of-sight communication (TV remotes, IR LANs). It cannot penetrate walls; used where line-of-sight is feasible.

unit3

Key elements

- **Transmitter:** IR LED + encoder (keyboard matrix → serial code → modulate).
- **Receiver:** PIN photodiode → amplifier → AGC → decoder → microcontroller.
- **Timing:** typical carrier ~455 kHz bursts for TV remotes; Manchester or biphase coding often used.

unit3

Exam tips

- 2-mark: list IR uses.
- 5-mark: draw block diagram of remote + receiver.
- 10-mark: explain encoder timing, modulation bursts and AGC role.

Wireless LAN (WLAN) & PANs

WLAN (Wi-Fi) essentials

- Based on **IEEE 802.11** family (802.11a/b/g/n etc.).
- Common deployment: infrastructure mode (AP connected to wired LAN), hotspots, home wireless router (residential gateway with NAT).

unit3

Standards & features

- 802.11b: 2.4 GHz, DSSS, up to 11 Mbps.
- 802.11a: 5 GHz, OFDM, up to 54 Mbps.
- 802.11g: 2.4 GHz OFDM, 54 Mbps (backwards compatible with b).
- 802.11n: MIMO, dual-band, up to hundreds of Mbps.
- Related: 802.11e (QoS), 802.11i (security/WPA/WPA2), 802.11s (mesh).

unit3

PANs

- PAN = Personal Area Network (Bluetooth most common). Bluetooth and ZigBee are used for PANs.

unit3

Exam tips

- 5-mark: draw WLAN config (AP ↔ wired LAN, hotspot, home router) and explain NAT.
- 10-mark: list standards with features (table), explain security (WEP vs WPA/WPA2).

 # Module 4 — Optical Communication

(Reference: unit4.pdf).

unit4

Optical principles

Core concepts

- **Light as EM wave:** optical frequencies higher than microwaves; often described by wavelength (nm/μm).
- **Reflection & refraction:** law of reflection (angle in = angle out); Snell's law for refraction ($n_1 \sin\theta_1 = n_2 \sin\theta_2$).
- **Critical angle & TIR:** if $\theta_{incidence} > \theta_{critical}$ when going from high → low n, total internal reflection occurs — fundamental for fibers.

unit4

Exam tips

- 2-mark: define TIR or Snell's law.
- 5-mark: show refraction diagram and derive condition for TIR (mention critical angle relationship).

Optical communication systems

Block diagram & function

- **Source (LED/laser)** → **Modulator** (intensity modulation / OOK / PCM) → **Transmission medium** (free space or fiber) → **Detector** (photodiode) → **Amplifier & demodulator**.

unit4

Key points

- Lasers produce coherent, monochromatic light for high data rates; LEDs for short links.
- Modulation: amplitude/intensity modulation or digital on-off keying (OOK).

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Exam tips

- 5-mark: draw block diagram, explain role of each block.
- 10-mark: compare LED vs laser transmitters, and explain receiver chain (photodiode + preamp + shaping).

Fiber-optic cables

Construction & types

- **Core** (glass/plastic) with higher refractive index, surrounded by **cladding** with lower index, plus protective jacket.
- **Types:** step-index multimode, graded-index multimode, single-mode.
    - *Step-index multimode:* large core, simple, more modal dispersion.
    - *Graded-index:* refractive index gradually decreases—reduces modal dispersion.
    - *Single-mode:* tiny core (2–15 μm), long-distance, needs laser.

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Important specs

- **Numerical aperture (NA):** determines acceptance cone (memorise definition & concept).
- **Attenuation (dB/km):** losses from absorption, scattering, and dispersion.
- **Bandwidth (MHz·km)** decreases with length.

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Exam tips

- 5-mark: explain construction and NA with diagram; list differences between single/multimode.
- 10-mark: discuss dispersion types and their impact on data-rate + methods to mitigate.

Optical transmitters & receivers

Transmitters

- **LEDs** for low cost/short links; **lasers** (LDs) for coherent, narrow beam, high-speed long distance.
- **Modulation:** direct on-off keying for digital; amplitude modulation for analog (e.g., some cable TV).

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Receivers

- **Photodiodes (PIN/APD)** convert light into current → amplification → demodulation.
- Sensitivity, noise, and bandwidth are important parameters.

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Exam tips

- 5-mark: compare LED vs laser; draw photodiode + amplifier block.
- 10-mark: explain APD vs PIN photodiode tradeoffs.

Wavelength Division Multiplexing (WDM)

Concept

- Multiplex several wavelength channels (λ1, λ2, ...) into one fiber to multiply capacity (basis for CWDM/DWDM). Used to reach 40/100 Gbps and beyond.

unit4

Components & advantages

- Mux/demux, optical amplifiers (EDFA) in DWDM systems. Enables huge capacity without laying more fibres.

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Exam tips

- 2-mark: define WDM.
- 5-mark: list components and benefits.
- 10-mark: describe DWDM vs CWDM and role of optical amplifiers.

Passive Optical Networks (PON) & 40/100 Gbps networks

PON essentials

- **FTTH** architectures use passive splitters to share a fiber among users (GPON, EPON). No active electronics between OLT (optical line terminal) and ONT (optical network terminal).

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40/100 Gbps networks

- Achieved via high bit-rate optical transmitters + WDM (DWDM) and improved fiber/dispersion compensation technologies.

unit4

Exam tips

- 5-mark: sketch PON layout and explain passive splitter role.
- 10-mark: explain how DWDM + lasers + dispersion compensation enables 40/100 Gbps links.

 # Module 5 — Satellite Communication

(Reference: UNIT 5.pdf).

UNIT 5

Satellite Orbits

Types & parameters

- **LEO (Low Earth Orbit):** ~400–1000 mi altitude, low latency (~10 ms), fast orbital speed (~17,500 mi/h).
- **MEO (Medium Earth Orbit):** ~1000–6000 mi, used for some navigation satellites.
- **GEO (Geostationary):** ~22,300 mi (35,888 km), 24-hr period appears stationary → ideal for TV/comms.
- **Other parameters:** apogee, perigee, inclination, azimuth, elevation — be able to define each and draw orbit geometry.

UNIT 5

Exam tips

- 2-mark: define GEO/LEO.
- 5-mark: compare LEO vs GEO (table).
- 10-mark: draw GEO geometry and discuss advantages/limitations (coverage vs delay).

Satellite Communication Systems

Basic operation

- **Uplink:** Earth station → satellite (higher frequency).
- **Transponder:** in satellite receives, amplifies, shifts frequency, retransmits on downlink.
- **Downlink:** satellite → earth station (lower frequency).
- **Typical freq pairs:** e.g., uplink ~6 GHz, downlink ~4 GHz for C-band; Ku ~14/12 GHz for newer systems.

UNIT 5

Exam tips

- 5-mark: draw block diagram showing uplink → transponder (freq translate + amp) → downlink.
- 10-mark: explain why frequency translation is necessary (prevent Tx desensitisation of receiver).

Satellite Subsystems

Major subsystems & functions

- **Communication subsystem:** transponders + antennas.
- **Telemetry, Tracking & Command (TT&C):** monitor satellite health and allow ground control to send commands.
- **Power subsystem:** batteries, solar arrays.
- **Propulsion subsystem:** apogee kick motor (AKM), thrusters for orbit raising & station-keeping.
- **Antenna subsystem:** shared Tx/Rx antennas often using diplexers.

UNIT 5

Exam tips

- 5-mark: list subsystems and primary functions.
- 10-mark: expand TT&C, propulsion and explain ground control interactions.

Ground Stations (Earth Stations)

Components & role

- **Antenna subsystem:** parabolic dish, diplexer to use same antenna for Tx/Rx.
- **Receive subsystem:** LNA, down-converters, demodulators — produce baseband to GCE.
- **Transmit subsystem:** up-converters, power amplifiers → antenna.
- **GCE (Ground Control Equipment):** demodulation, multiplexing/demultiplexing, telemetry interfaces.

UNIT 5

Exam tips

- 5-mark: draw an earth station block diagram and label LNA, down-converter, up-converter, diplexer.
- 10-mark: explain receive chain (LNA → down conversion → demodulation) and transmitter chain.

Satellite Applications

Major uses

- Broadcasting (TV), telecommunications, internet backhaul, remote sensing, weather forecasting, GNSS (positioning), mobile satellite services.

UNIT 5

Exam tips

- 2-mark: list 3 applications.
- 5-mark: describe 2 applications (e.g., TV broadcasting & GNSS) including why satellites are suited.

GNSS (Global Navigation Satellite System)

Definition & segments

- GNSS provides global positioning, navigation and timing via satellite constellations (e.g., GPS, GLONASS, Galileo).
- **Segments:** Space segment (satellites broadcasting signals), Control segment (ground stations that monitor & correct satellites), User segment (receivers that compute position/time from signals).

UNIT 5

Exam tips

- 5-mark: name the three segments and their roles.
- 10-mark: explain how receivers use time-of-arrival from multiple satellites to compute position (multilateration concept — use simple geometry/diagram).