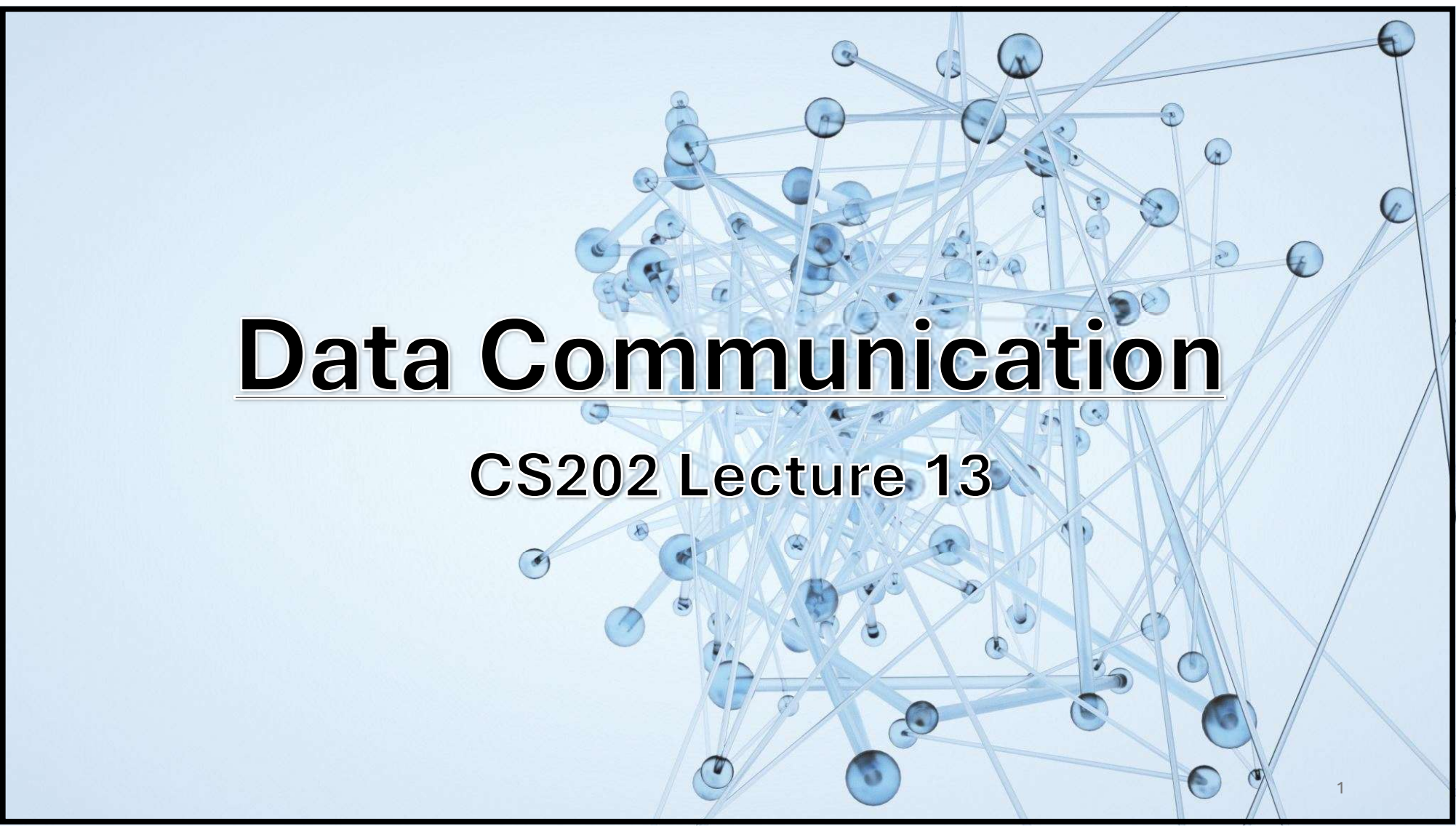


Data Communication

CS202 Lecture 13

Topics Covered In Last Lecture

- Data Communications (Model, Process and Types)
- Modulation Techniques & Error Detection (CRC etc.)
- Data Transmission (Mediums)

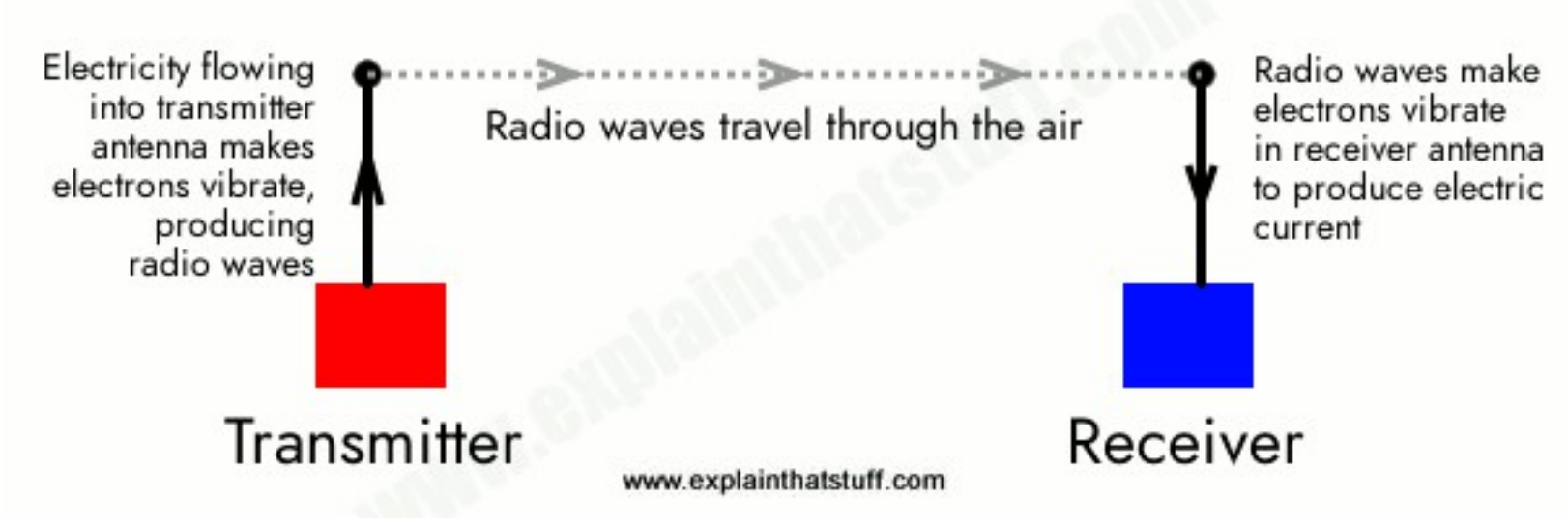
Sequence of Content

- Data Transmission (Mediums cont., Modes and Methods)
- Synchronous and Asynchronous Transmission
- Modems (Types and Functions)

Radio Waves

- **Radio** is an invisible game of throw-and-catch. Instead of throwing a ball from one person to another, you send information, coded as a pattern of electricity and magnetism, from a transmitter (the thrower) to a receiver (the catcher) — both of which are kinds of antennas.

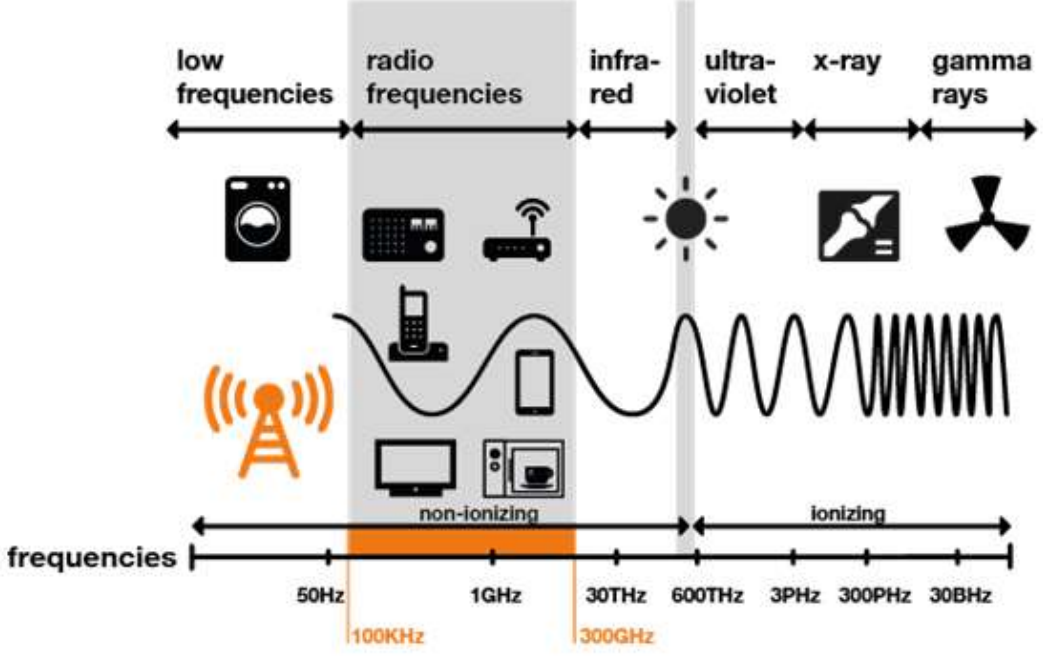
- The **transmitter** is a piece of equipment that turns electrical signals (such as the sound of someone speaking, in radio, or a picture, in TV) into an oscillating electromagnetic wave that beams through the air, in a straight line, at the speed of light (300,000 km 186,000 miles per second).



Radio Waves

- The **receiver** is a mirror-image piece of equipment that catches the waves and turns them back into electrical signals—so we can recreate the radio sounds or TV pictures.

- **Wireless Internet** is simply a way of using radio waves to send and receive Internet data instead of radio sounds or TV pictures.



5G: Fifth Generation of Wireless Cellular Technology

Speed:

- 5G achieves speeds of 10 gigabits a second (10 times faster than 4G)
- Peak data rates reaching up to 20 gigabits per second (Gbit/s)
- Seamless streaming, gaming, and data transfers

Key Features:

- **Latency** as low as **1 millisecond** enables near-instant communication, crucial for real-time applications like autonomous vehicles and remote surgery
- 5G can **connect billions of devices**, supporting the Internet of Things (IoT) and smart cities

5G: Fifth Generation of Wireless Cellular Technology

Frequency Bands: 5G operates in three main bands:

- **Low-band:** Similar frequencies to 4G (600-900 MHz), offering broader coverage but lower speeds
- **Mid-band:** Frequencies like 3.3-4.2 GHz balance speed and coverage
- **High-band (mmWave):** Frequencies above 24 GHz offer super-fast speeds but shorter ranges

Why high-frequency signals typically have a shorter range compared to low-frequency signals?

Key Factors:

1. **Attenuation:** High-frequency signals tend to attenuate (weaken) more rapidly in media like air, water, or solids
2. **Wavelength:** Lower frequency signals have longer wavelengths; higher frequency signals have shorter wavelengths

- **Propagation Characteristics:** Low-frequency waves (longer wavelengths) diffract more around obstacles; high-frequency waves are more directional
- **Cellular Networks:** Higher frequency bands (like mmWave in 5G) have shorter ranges

Why high-frequency signals typically have a shorter range compared to low-frequency signals?

Applications: Communication Systems: Frequency choice balances range, bandwidth, antenna size

Considerations

- **Antenna Size:** Lower frequencies often need larger antennas
- **Bandwidth vs Range Trade-offs:** Higher frequencies can offer more bandwidth.

High-Speed Optical Fiber Communication Systems

Key Data Rates

- **Commercial Systems:** Current commercial systems can reach speeds of up to **100 terabits per second (Tbps)**
- **Research Breakthroughs:** Researchers have achieved record-breaking speeds like **1.02 petabits per second (Pbps)** over **1,808 kilometers** using a 19-core optical fiber with standard cladding diameter
- **Experimental Achievements:** Teams have demonstrated 402 Tbps using multiple wavelength bands in commercial-grade fiber

High-Speed Optical Fiber Communication Systems

Applications

- **Long-Haul Telecom:** High-capacity backbone networks
- **Data Centers:** Fast interconnects for cloud services
- **Undersea Cables:** Transcontinental connectivity

Wireless Fidelity (Wi-Fi)

- A wireless networking technology that allows devices such as computers, smartphones, and other equipment to connect to the internet or **communicate with one another without the need for physical cables**
- Uses radio waves to transmit data over short to medium distances, typically within a range of **100 to 300 feet** indoors, depending on the environment and equipment
- **Commonly Used Frequency Bands:**
  - **2.4 GHz band:** Offers wider coverage but slower speed; more prone to interference
  - **5 GHz band:** Provides faster data rates with less interference but shorter range
  - **6 GHz band (Wi-Fi 6E):** Newer band offering higher capacity, faster speeds, and lower latency for modern devices

Advantages/Disadvantages of 2.4 GHz Band

Advantages	Disadvantages
Longer Range: 2.4 GHz signals travel farther and can cover larger areas, making them suitable for bigger homes or offices.	**Slower Speeds:** 2.4 GHz typically offers slower data transfer rates, up to 300-600 Mbps.
Better Penetration: These signals can pass through walls, floors, and other solid objects more easily.	**More Interference:** This band is prone to interference from other devices like microwaves, Bluetooth devices, and baby monitors, due to its popularity and limited non-overlapping channels.
Widespread Compatibility: Almost all Wi-Fi-enabled devices support 2.4 GHz.	**Congestion:** With many devices using 2.4 GHz, networks can become congested.

Advantages/Disadvantages of 5 GHz Band

Advantages	Disadvantages
Faster Speeds: 5 GHz offers significantly higher speeds, up to 1300 Mbps, ideal for streaming, gaming, and high-bandwidth activities.	**Shorter Range:** 5 GHz signals have a shorter effective range and are more susceptible to being weakened by obstacles like walls.
Less Interference: With more channels (23 non-overlapping channels), 5 GHz experiences less congestion compared to 2.4 GHz.	**Weaker Penetration:** These signals struggle more with passing through solid objects.
More Bandwidth: Supports higher bandwidth applications.	**Device Compatibility:** Not all devices support 5 GHz; it's more common in modern devices.

Application Areas of 2.4 and 5 GHz Bands

- **2.4 GHz:** Larger spaces, devices far from the router, IoT devices, and applications where speed isn't critical

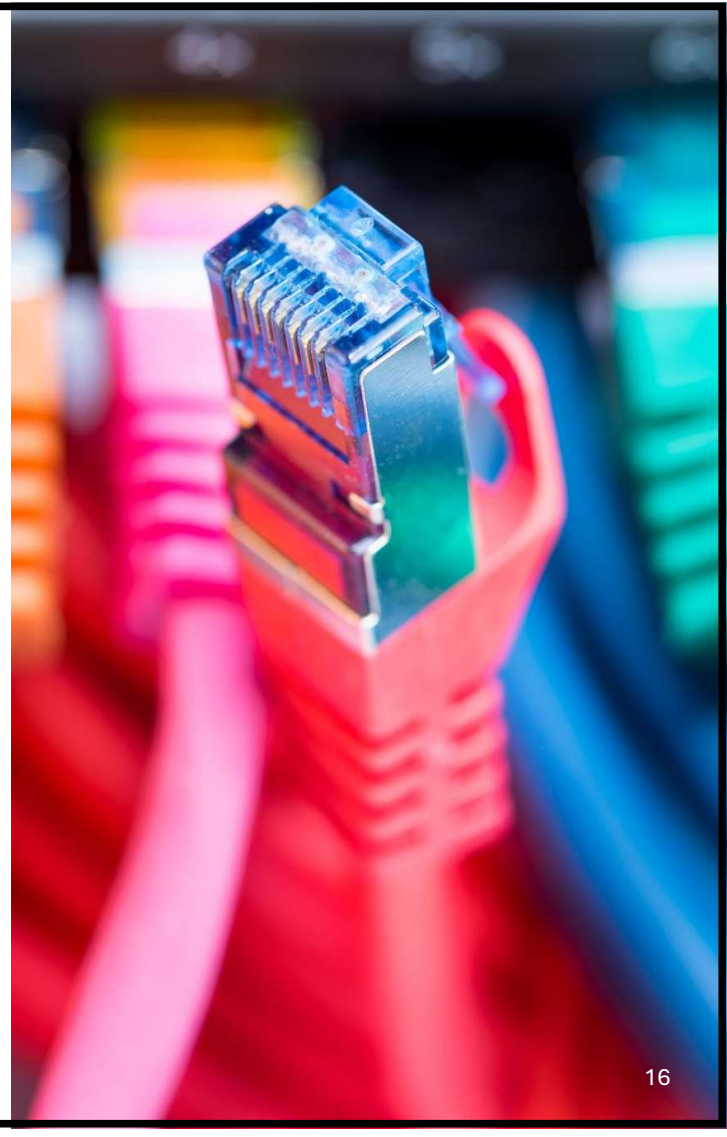
- **5 GHz:** High-speed needs like streaming HD videos, gaming, video calls; ideal when you're closer to the router in less obstructed spaces

- **Dual-Band Routers:** Many modern routers support both 2.4 GHz and 5 GHz, allowing devices to connect to the best-suited band

Transmission Modes

Serial Transmission: Data sent one bit at a time over a single channel

Parallel Transmission: Multiple bits sent simultaneously over multiple channels



Transmission Methods

Synchronous: Continuous data flow, synchronized by a clock signal.

Asynchronous: Data sent at irregular intervals, using start and stop bits.

Synchronous Transmission

Characteristics:
- Continuous data transmission in large blocks
- Synchronized by a shared clock
- No start/stop bits

Advantages:
- Faster and more efficient
- Ideal for high-volume data transmission

Disadvantages:
- More complex hardware
- Requires continuous data flow

Asynchronous Transmission

Characteristics:

- Data sent one byte at a time
- Uses start/stop bits for synchronization
- No shared clock

Advantages:

- Simple and cost-effective
- Flexible timing

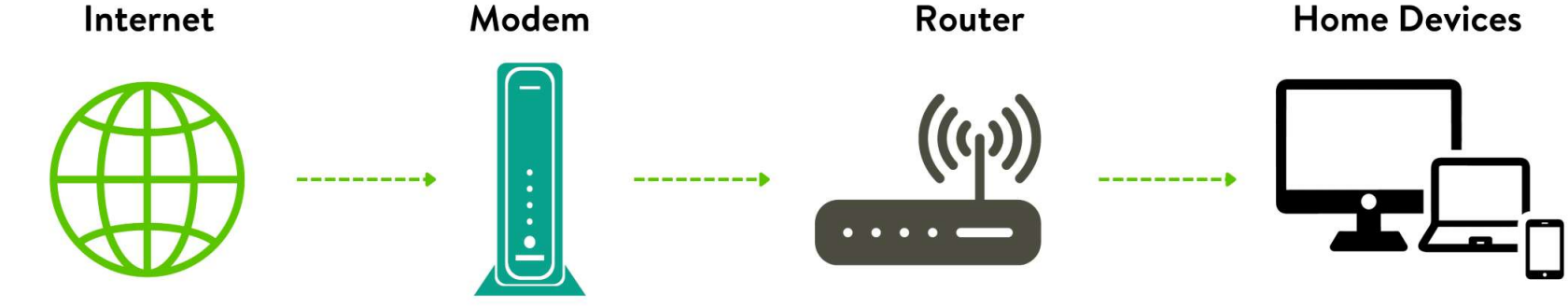
Disadvantages:

- Slower speeds due to start/stop bits
- Higher overhead

Modems

What is a Modem?
Device that converts digital data to analog signals and vice versa for transmission over analog lines

Key Functions:
- **Modulation**: Converts digital data to analog signals
- **Demodulation**: Converts analog signals back to digital data



Types of Modems

- **Dial-up Modem**: Connects via telephone line; slow (up to 56 Kbps)
- **DSL Modem**: Uses telephone lines, faster than dial-up
- **Cable Modem**: Uses coaxial cable, high speeds (20 Mbps to 1 Gbps)
- **Fiber Optic Modem**: Transmits data via light signals, gigabit speeds
- **Wireless Modem**: Connects to cellular networks (4G, 5G)
- **Satellite Modem**: Used for remote locations, higher latency

Modem or Router?

MODEM

A modem is the connection between your house and the internet.

A modem does not require a router to function.

ROUTER

A router is the connection between your modem and your wireless devices.

A router does need a modem to function.

Wireless Devices

Source: *https://www.earthlink.net/blog/difference-between-modem-and-router/*

Modem Functions

- **Sending Data**: Modem converts digital data into transmittable analog signals
- **Receiving Data**: Modem demodulates incoming analog signals into digital data for the receiving device
- **Protocols**: Use of error detection and correction mechanisms to ensure data integrity
- Creates a local network but **no internet backhaul**

Case Study 1: Data Transfer Inside a Computer

Background:

Inside a computer, data is transferred between the CPU and RAM. To make the transfer **very fast**, the system uses **multiple wires** so that several bits are transmitted **at the same time**.

Question:

Which **transmission mode** discussed in this lecture is being used here?

Case Study 1: Data Transfer Inside a Computer

Background:

Inside a computer, data is transferred between the CPU and RAM. To make the transfer **very fast**, the system uses **multiple wires** so that several bits are transmitted **at the same time**.

Question:

Which **transmission mode** discussed in this lecture is being used here?

Answer:

Parallel Transmission – because multiple bits are transmitted simultaneously across multiple wires.

Case Study 2: Pop-Up Command Center Connectivity

Background:

A disaster-response team must bring internet connectivity to a **pop-up command center** in a rural area (2-10 km) **within 6 hours**.

On-site constraints:

- **No fiber/DSL/cable service** in the area (confirmed with local providers).
- **Strong 4G/5G coverage** from multiple carriers.
- Must support **25 laptops + 10 tablets** for maps, email, VoIP, and periodic file sync.
- Target **uplink ≥ 10 Mbps**, **latency < 100 ms** for reliable VoIP and mapping.
- Minimal gear, quick setup, and portable power.

Case Study 2: Pop-Up Command Center Connectivity

Problem Solving:

- Concurrent traffic estimate:
  - VoIP: ~10 concurrent calls × 100 kbps ≈ **1 Mbps**
  - Mapping/data sync bursts: ~5–8 Mbps typical
  - Overhead + headroom: ≈ **10–12 Mbps uplink** required
- Local distribution via Wi-Fi is fine, but **Wi-Fi alone doesn't provide WAN** (it's a LAN technology).

Case Study 2: Pop-Up Command Center Connectivity

Options (comparative analysis):

- **Wi-Fi Router only**
- **DSL/Cable Modem** – requires fixed wired infrastructure **not available** here.
- **Satellite Terminal** – works anywhere but **high latency** (hundreds of ms) hurts VoIP/interactive maps; higher cost & setup time.
- **4G/5G Cellular Modem** (with integrated Wi-Fi or paired router) – uses **radio waves** to reach the carrier network; quick to deploy; typical uplink and latency meet the target. Typical range 2-10 km.

Case Study 2: Pop-Up Command Center Connectivity

Question:

Given the constraints, **which device should be deployed to provide internet backhaul for the pop-up command center?**

Case Study 2: Pop-Up Command Center Connectivity

Question:

Given the constraints, **which device should be deployed to provide internet backhaul for the pop-up command center?**

Answer: 4G/5G Cellular Modem (paired with/inside a Wi-Fi router)

- Only option that **meets all constraints simultaneously**: no fixed lines needed, fast to deploy, **sufficient uplink and acceptable latency**, and scales to the required number of users.
- Other options fail a critical requirement (no backhaul, unavailable infrastructure, or excessive latency).

Summary

Data Transmission: Can be analog or digital, using serial or parallel modes

Communication Media: Radio Waves

Transmission Methods: Asynchronous is simple and flexible, while synchronous is faster and efficient

Modems: Enable communication by converting signals between digital and analog formats