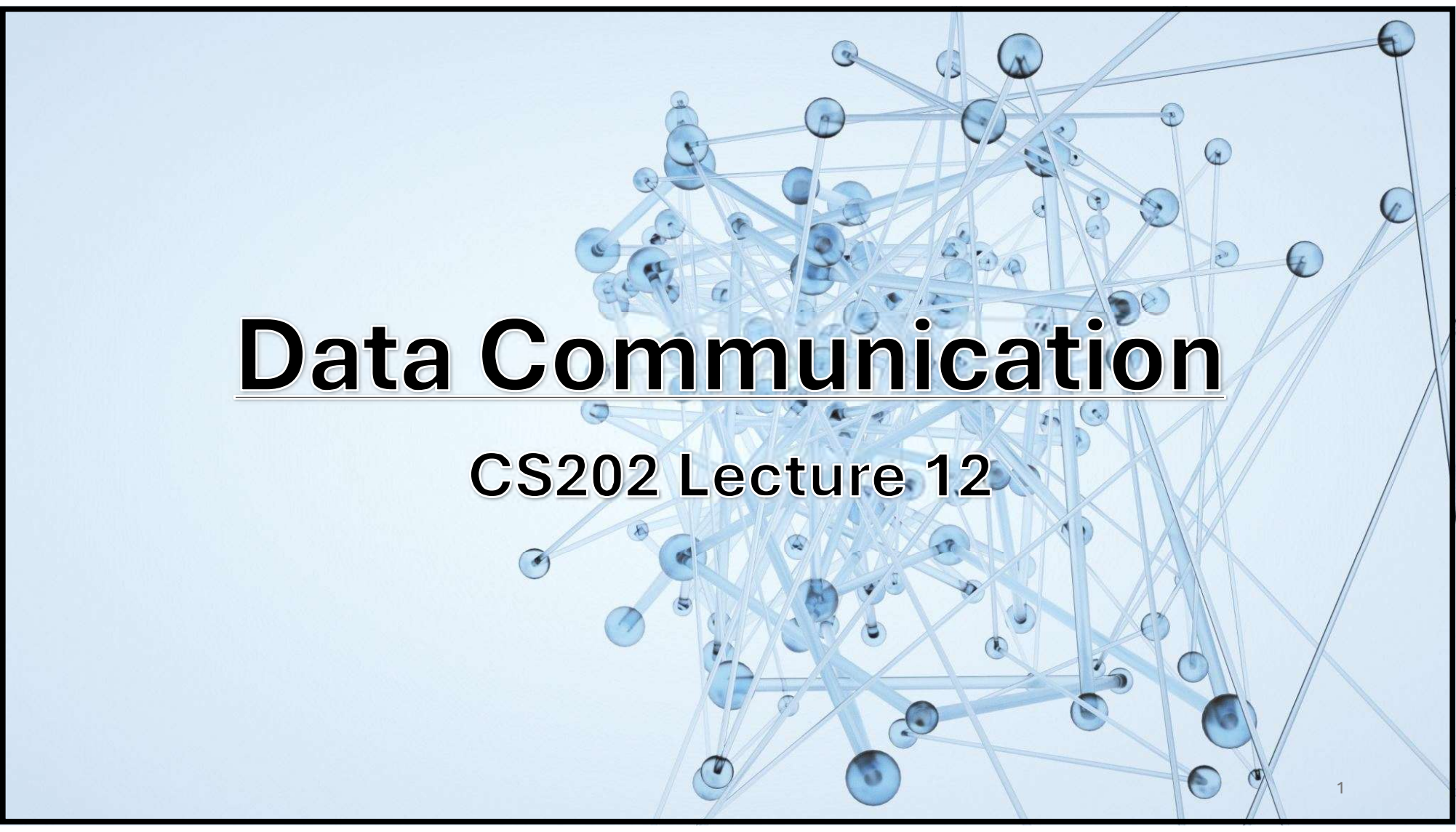


Data Communication

CS202 Lecture 12

Topics Covered In Last Lecture

- Storage devices and media
  - Learning Objectives
  - Intro to Storage Media and Devices
  - How do we measure storage capacity?
  - Classification of storage media according to size
  - How is data accessed from these drives?
  - Different magnetic media and magnetic storage devices; magnetic disk and tapes
  - Optical media and optical storage devices
  - Solid-state media and solid-state storage devices
  - Cloud storage
  - Redundant Array of Independent Disks (RAID)
  - Storage Area Network (SAN)

Today's Topics

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

Data Communications

- Exchange of data between devices or systems through transmission mediums such as cables, wireless signals, or optical fibers

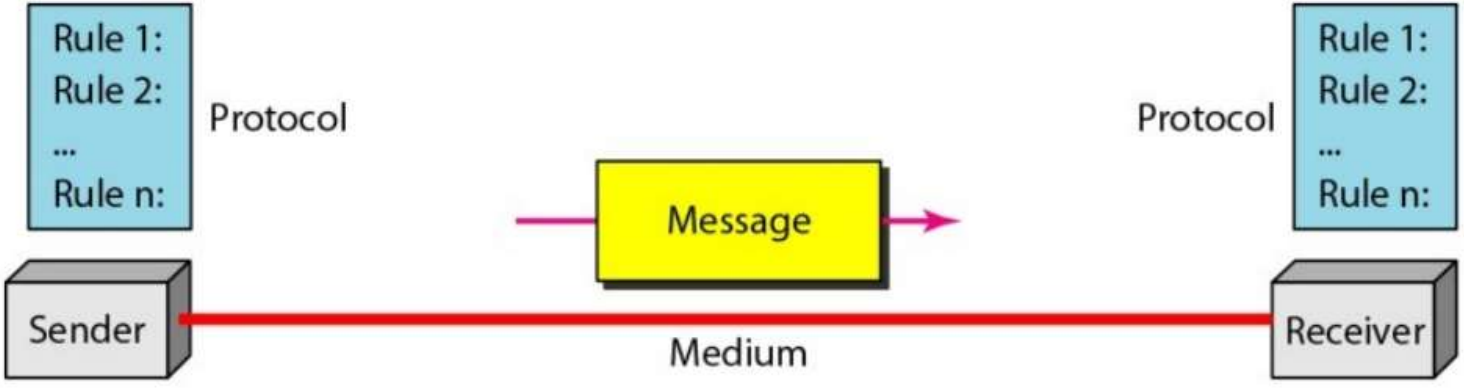
- Transfer of digital or analog data using standardized protocols that ensure the accurate and efficient delivery of information

Data Communication Model

Data Communication Model refers to the framework for transmitting data between sender and receiver

Components:

Sender, Receiver, Message, Transmission Medium, Protocol



Data Communication Process

- **Encoding & Modulation**: Sender converts data into transmittable signals
- **Transmission**: Data moves through the medium
- **Demodution & Decoding**: Receiver converts the signal back into usable data
- **Error Detection**: Mechanisms like parity or Cyclic redundancy check (CRC) to ensure data integrity

Modulation

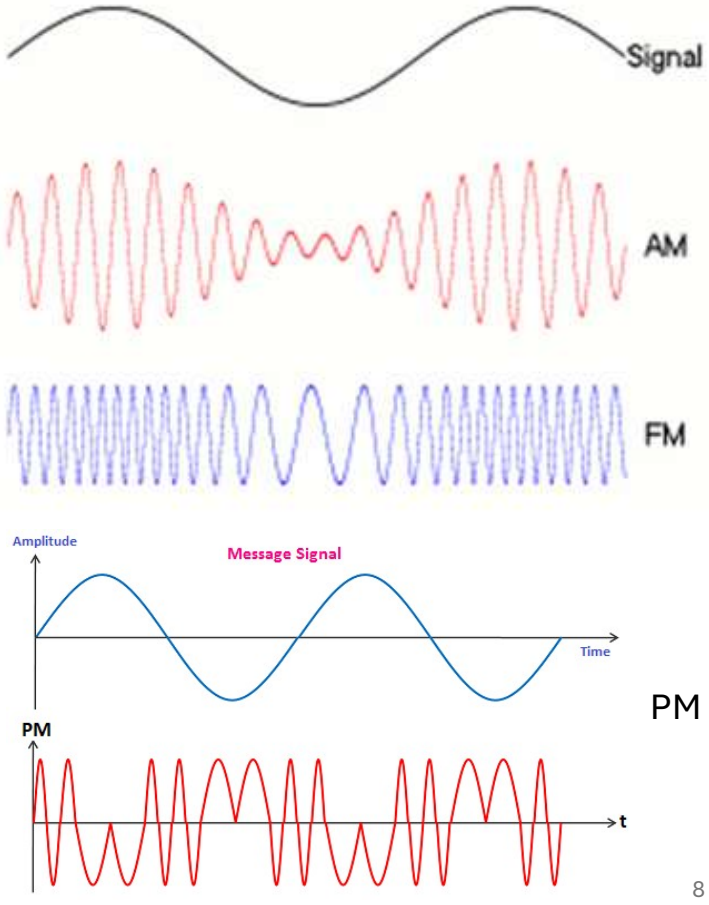
- **Modulation** is the process by which the message signal is included in the properties of a high-frequency carrier.
- A carrier is a high-frequency sinusoid and it has the following parameters:
- Amplitude, Frequency, Phase
- Modulation is performed by varying one of the carrier parameters in proportion to the baseband signal.
- Accordingly, we have Amplitude Modulation (AM), Frequency Modulation (FM) and Phase Modulation (PM)
- At the receiver, the inverse operation is performed. This is called “Demodulation.”
- **Demodulation** is the process of recovering the message signal from the modulated carrier.

Modulation Techniques

Amplitude Modulation (AM): Translating the varying signal into variations in the amplitude of a carrier sine wave at a frequency of several kilohertz

Frequency Modulation (FM): Modulation in which the frequency of the carrier wave is altered in accordance with the instantaneous amplitude of the modulating signal, keeping phase and amplitude constant

Phase modulation (PM): Modulation pattern which encodes a message signal as variations in the instantaneous phase of a carrier wave



Error Detection

- Error detection in data communication ensures that the data received at the destination is the same as the data transmitted from the source.
- Errors can occur due to noise, interference, or other issues during transmission.
- Error detection techniques help identify whether data has been corrupted during transmission.

Error Detection

Common Error Detection Methods:

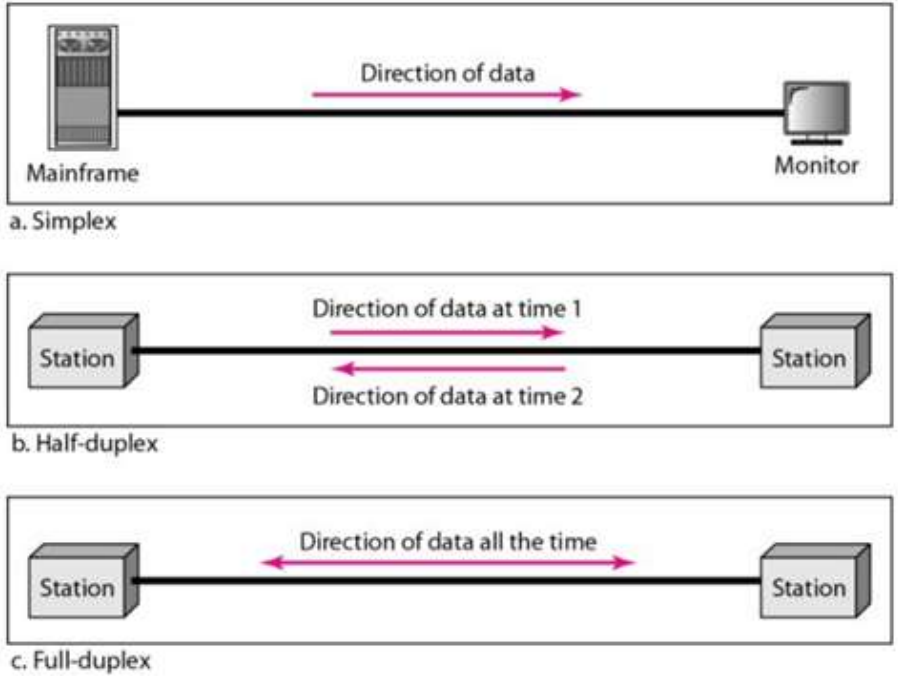
1. **Parity Check:** A parity bit is added to the data to make the number of 1s either even (even parity) or odd (odd parity). If the number of 1s does not match the expected parity at the receiver, an error is detected.
2. **Checksum:** The sender calculates the sum of the data values and sends this checksum along with the data. The receiver recalculates the checksum. If the calculated checksum does not match the transmitted one, an error is detected.
3. **Cyclic Redundancy Check (CRC):** The transmit end calculates a check code for the data in a data frame based on a certain algorithm, appends the check code to the data frame, and sends the data frame to the receive end.
4. **Hamming Code:** This technique not only detects but also corrects single-bit errors. It uses redundant bits placed at specific positions in the data to detect and correct errors.
5. **Frame Check Sequence (FCS):** Similar to CRC, FCS is used in networking protocols like Ethernet. The sender adds a frame check sequence to the end of a data frame, which is verified by the receiver.

Types of Data Communication

a. **Simplex**: One-way communication (e.g., TV broadcast)

b. **Half-Duplex**: Two-way communication, but not simultaneous (e.g., walkie-talkie)

c. **Full-Duplex**: Simultaneous two-way communication (e.g., phone calls)

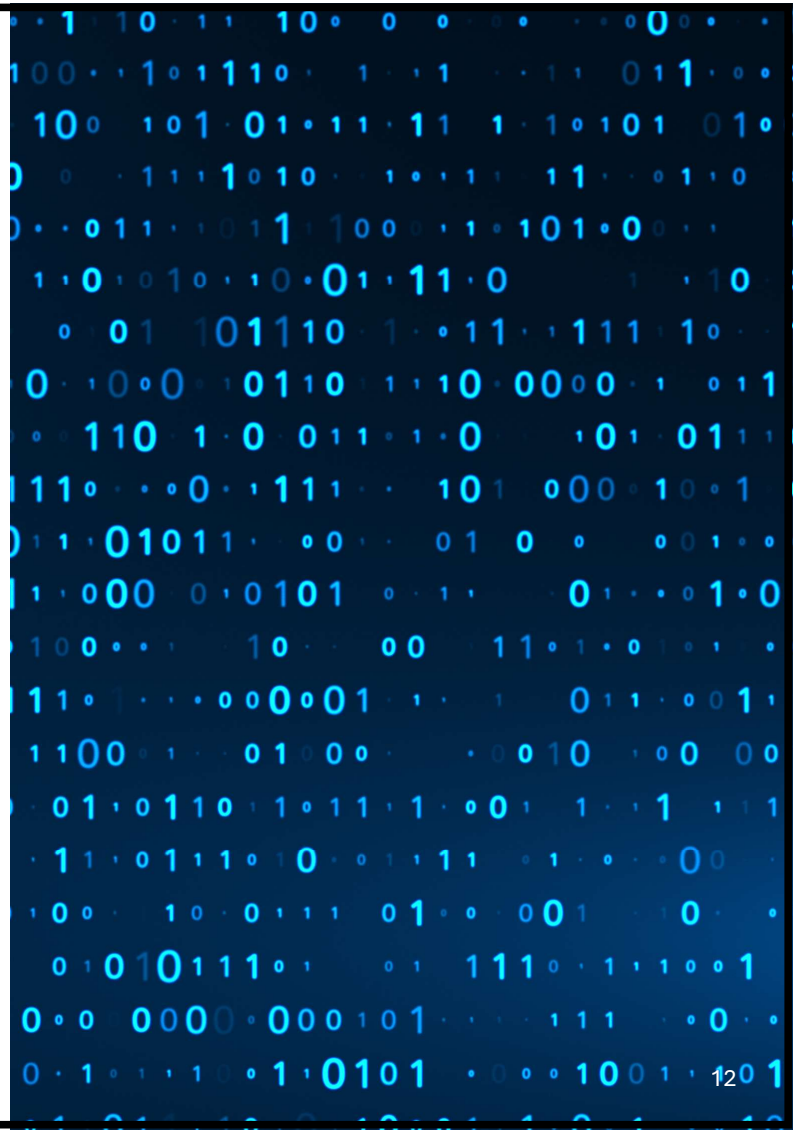


Data Transmission

Data Transmission: The process of sending data from one place to another.

Transmission Types:

- **Analog**: Continuous signals, e.g., AM/FM radio.
- **Digital**: Discrete signals (0s and 1s), e.g., computer networks.



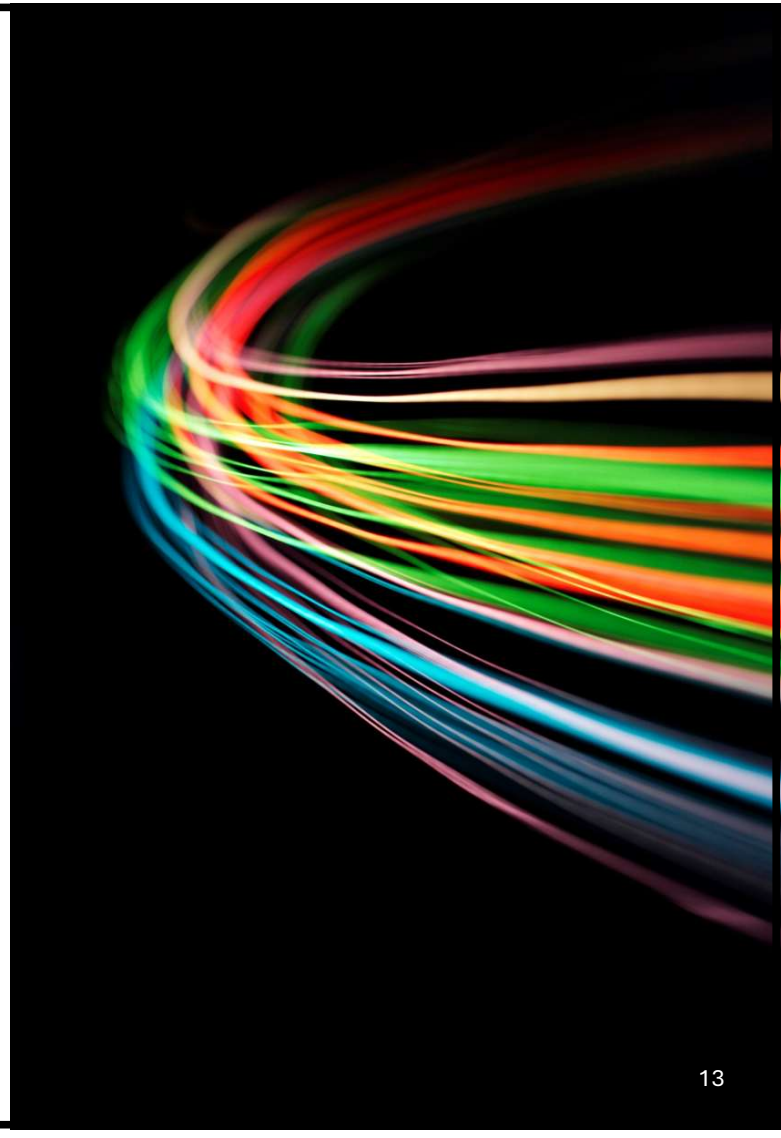
Transmission Mediums

Wired (Guided):

Twisted pair cables, coaxial cables, fiber optics

Wireless (Unguided):

Radio waves, microwaves, infrared, satellite

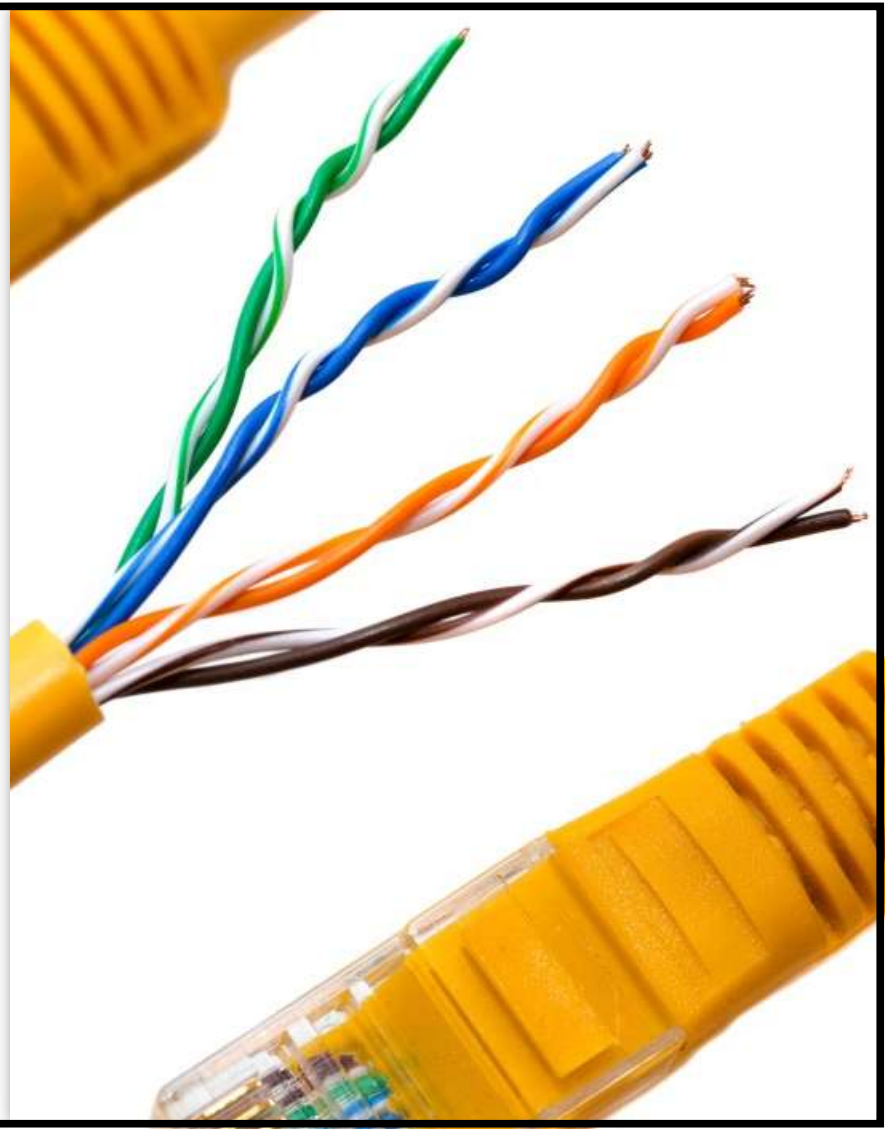


Twisted Pair Cables

- A type of wiring where two conductors are twisted together to reduce electromagnetic interference (EMI) from external sources and crosstalk between adjacent wires

Characteristics:

- **Twists:** The twisting cancel out noise
- **Transmission Distance:** For shorter distances (up to 100 meters for Ethernet)
- **Bandwidth:** Supports speeds depending on the category of the cable (e.g., Cat5e, Cat6, Cat7)



Coaxial Cables

- Electrical cable consisting of a central conductor, an insulating layer, a metallic shield, and an outer insulating layer
- Offer better protection from interference compared to twisted pair cables due to their shielding

Characteristics:

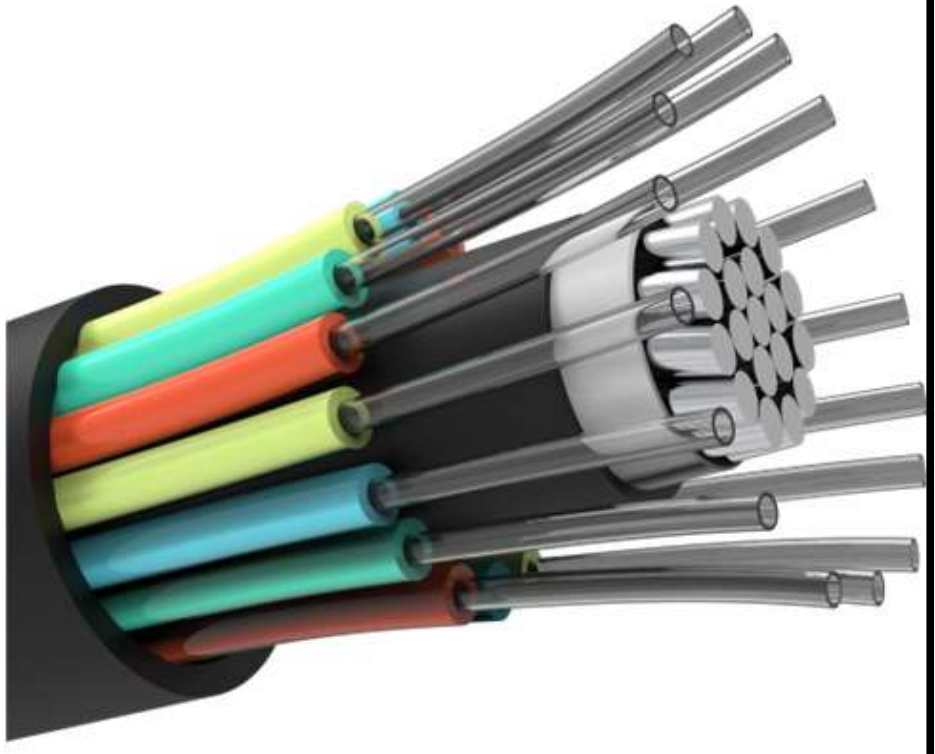
- **Impedance:** Commonly rated at 50 ohms (for RF signals) or 75 ohms (for video signals)
- **Bandwidth:** Supports a wide range of frequencies, making it suitable for high-speed data and video transmissions
- **Distance:** Coax cables can transmit data over longer distances without significant loss compared to twisted pair cables

Fiber Optics

- Fiber Optic Cables are advanced communication cables that use light to transmit data.
- Made of glass or plastic fibers

Characteristics:

- **Speed:** Can transmit data at extremely high speeds (up to terabits per second) due to the use of light instead of electrical signals
- **Bandwidth:** Offers much higher bandwidth than copper cables, allowing for more data to be transmitted over the same cable
- **Distance:** Can transmit data over much longer distances without the need for signal boosters or repeaters
- **Resistance to Interference:** Immune to electromagnetic interference (EMI) and radio frequency interference (RFI), making it ideal for environments with a lot of electrical noise



Case Study 1: Reliable Data Transfer for a Stock Exchange

Background:

A stock exchange needs to transmit **real-time trading data** between its servers and broker terminals. The data must:

- Travel **fast** with minimal delay
- Be **reliable**, since even a single bit error could cause huge financial losses
- Support **high bandwidth** to handle thousands of transactions per second

Question:

Which **transmission medium** and **error detection technique** discussed in this lecture would be most suitable for this system?

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Question:

Which **transmission medium** and **error detection technique** discussed in this lecture would be most suitable for this system?

Answer:

- **Optical Fiber** as the transmission medium → because it offers very high speed, large bandwidth, and immunity to electromagnetic interference.
- **Cyclic Redundancy Check (CRC)** for error detection → because it is highly reliable in detecting transmission errors in large data streams.

Case Study 2: Zero-Downtime Medical Imaging Link

Background:

Two partner hospitals, 28 km apart, must stream **real-time diagnostic imaging** (radiology consoles and 4K endoscopy video) to a joint tumor board. The IT brief requires:

- **Sustained throughput ≥ 8 Gbps** (multiple concurrent 4K streams + overhead)
- **One-way latency < 5 ms** and **jitter < 1 ms** (for synchronized review)
- **99.999% availability** with **strong error detection** at the data link
- The route passes near heavy industrial zones with **high EMI**; **no guaranteed line-of-sight** for rooftop links; existing **underground duct** is available
- Data must remain on a **private network** (regulatory/privacy constraints)

Case Study 2: Zero-Downtime Medical Imaging Link

Quick Calculation (problem solving):

- 6 concurrent 4K streams at a conservative **1.2 Gbps each (visually lossless, mezzanine) ≈ 7.2 Gbps**
  - Ancillary data (EHR sync, control channels, overhead) ≈ **0.8–1.2 Gbps**
- ⇒ Practical headroom target: **≥10 Gbps** sustained, low-latency, error-checked.

Options under consideration (for comparative analysis):

- **Copper (Cat6a/Cat7)** — distance limits (~100 m per segment), susceptible to EMI, repeaters add latency/failure points.
- **Licensed Microwave / 5G** — variable latency/jitter; weather/LOS constraints; public spectrum/core dependencies.
- **Satellite** — latency orders of magnitude higher; unsuitable for real-time review.
- **Optical Fiber** — long distance, immune to EMI, supports 10–100 Gbps, deterministic low latency; Ethernet frames protected by **CRC-32** at Layer 2.

Case Study 2: Zero-Downtime Medical Imaging Link

Question:

Given the constraints, **which transmission medium should be selected for the inter-hospital link, and why**?

Case Study 2: Zero-Downtime Medical Imaging Link

Question:

Given the constraints, **which transmission medium should be selected for the inter-hospital link, and why**?

Answer: Optical Fiber

- **Meets all requirements simultaneously:** high throughput (10–100 Gbps), **low latency/jitter**, **EMI immunity**, long-distance support via the available **underground duct**, and private end-to-end control.
- **Data communications model fit:** Source (imaging systems) → Transmitter (optical transceivers) → **Channel (fiber)** → Receiver → Destination; noise (EMI) impact is negligible on fiber.
- **Modulation & error detection:** Standard optical Ethernet uses digital line/optical modulation in the PHY and **CRC-32** at the data link layer for robust **error detection** without heavy processing delay.
- **Type: Full-duplex, synchronous** operation over switched Ethernet provides deterministic performance needed for concurrent real-time streams.

Case Study 3: Choosing the Right Transmission Medium

Background:

A bank wants to connect two of its offices that are **20 km apart**. The link must carry daily transactions, video conferencing, and backups. The connection should be **fast, reliable, and secure**.

Question:

As the bank's ICT consultant, evaluate the available transmission mediums (twisted pair, coaxial cable, wireless, satellite, and optical fiber) in terms of ***distance, speed, reliability, and security****. Based on this comparison, which medium should the bank choose, and why?*

Case Study 3: Choosing the Right Transmission Medium

Answer:

The most suitable medium is **single-mode optical fiber**.

Twisted Pair (Copper Cables):

Twisted pair cables are inexpensive and common for local networks, but they work reliably only up to 100 meters. Extending them to 20 km would require repeaters, which add latency, increase failure points, and reduce overall reliability. They are also highly susceptible to electromagnetic interference, which is unacceptable for secure banking data.

Case Study 3: Choosing the Right Transmission Medium

Answer:

Coaxial Cable:

Coaxial can transmit data farther than twisted pair and is more resistant to noise, but it still cannot handle modern requirements of multi-gigabit speeds over 20 km. It is largely outdated for enterprise backbones.

Wireless (Microwave / Wi-Fi):

Wireless can cover long distances and allows quick setup, but weather conditions such as rain and storms affect reliability. For a bank, even a short interruption in connectivity could delay transactions or disrupt video conferencing. Wi-Fi is not viable at this scale, and microwave links depend on line-of-sight, which may not be guaranteed in an urban environment.

Case Study 3: Choosing the Right Transmission Medium

Answer:

Satellite:

Satellite coverage spans large areas, but latency is too high (hundreds of milliseconds) for real-time banking operations. Video conferencing would suffer, and financial transactions could be delayed. Satellites also bring high cost and security concerns.

Optical Fiber (Single-Mode):

Single-mode fiber is ideal for the bank's needs. It can easily cover 20 km without repeaters, supports extremely high speeds (10 Gbps+), and is immune to EMI, ensuring secure and uninterrupted communication. Latency is very low, making it perfect for both financial data and video conferencing. Fiber is also scalable, allowing future growth without changing the infrastructure.

Case Study 3: Choosing the Right Transmission Medium

Answer:

Conclusion:

When compared across **distance, speed, reliability, and security**, only **single-mode optical fiber** meets all requirements. It is the clear choice for connecting the bank's two offices.

Summary

Data Communication: Involves sender, receiver, message, medium, and protocols

Communication Media: Twisted Pairs, Coaxial Cables and Optical Fibers