"TRADITIONAL VS. MODERN TRANSMISSION MEDIA: A COMPARATIVE STUDY OF WIRED AND WIRELESS TECHNOLOGIES IN TODAY'S COMMUNICATION ECOSYSTEM"

SUBMITTED BY

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1 .INTRODUCTION

1.1 BRIEF OVERVIEW OF COMMUNICATION SYSTEM

A communication system is a combination of hardware and software that enables the exchange of information between two points — typically a transmitter and a receiver. The system may include devices such as data terminals, transmission equipment, relay stations, and auxiliary units. It provides the pathway for signals to travel from the source to their intended destination.

The key parts of any communication system are the transmitter, the transmission channel, and the receiver. Before data can be sent, it undergoes a series of processes such as encoding, modulation, and signal shaping. Once prepared, the signal passes through the chosen transmission medium to reach its destination.

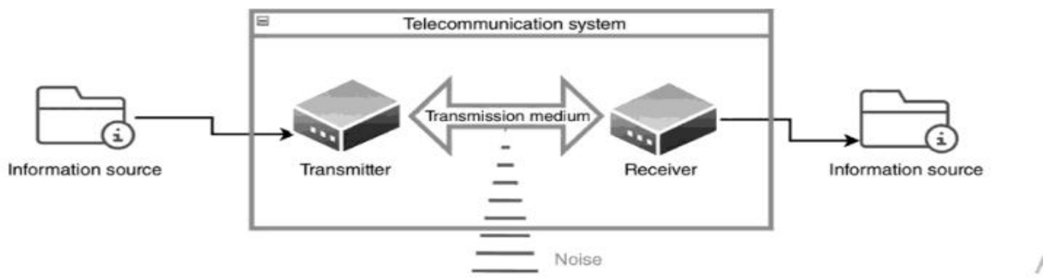

Fig 1. Block Diagram of Communication System

1.2 IMPORTANCE OF TRANSMISSION MEDIA

Transmission media act as the pathway between the sender and receiver, enabling the transfer of data. This path may be **physical**, like copper wires or fiber-optic cables, or **wireless**, such as radio waves or infrared signals. The choice of medium greatly impacts the **speed, reliability, and security** of a network.

1.2.1 Characteristics of Transmission Media

- **Bandwidth:** Determines the volume of data that can be transmitted per second. Higher bandwidth is essential for high-speed applications.

- **Delay and Latency:** Refers to the time it takes for data to travel between devices. Low latency is critical for real-time activities such as online meetings or gaming.

- **Cost and Maintenance:** Installation and upkeep costs differ depending on the medium. For example, twisted-pair cables are inexpensive, whereas fiber optics are more costly and complex to set up.

1.3 Comparison between traditional (wired) and modern (wireless) technologies.

Wired networks, though highly reliable and fast (especially fiber optics), limit mobility because they require a fixed physical connection. Any relocation or reconfiguration often means additional installation costs and effort.Wireless technologies, particularly 5G and other advanced cellular systems, now provide speeds comparable to — and in some cases exceeding — wired broadband. They offer unmatched mobility, making them ideal for industries and applications where flexibility is essential. For example, businesses in remote locations can use wireless networks to deploy IoT devices or sensors where running cables would be impractical.

2. OVERVIEW OF TRANSMISSION MEDIA

Transmission media refers to the physical channels that carry signals from one device to another.It can be classified into two categories ,guided and unguided transmission media.

Each of these categories includes various types of transmission media, each with its unique characteristics, advantages, and disadvantages.

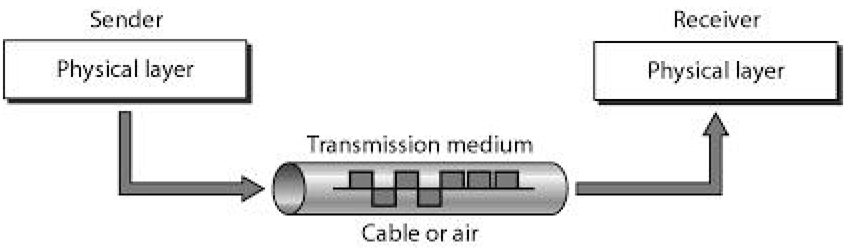

Fig 2. Transmission medium and Physical Layer

Transmission media are the channels through which data signals travel from one device to another. These pathways can be **physical** or **wireless**, each designed to suit specific communication requirements. In networking, the choice of medium affects the **speed**, **distance**, and **reliability** of the connection.

Broadly, transmission media can be divided into two main categories:

1. **Guided Media (Wired):** Data travels through a solid physical conductor such as twisted-pair cables, coaxial cables, or optical fibers.
2. **Unguided Media (Wireless):** Signals move through open space, such as air or vacuum, using electromagnetic waves like radio, microwave, or infrared.

In everyday life, different forms of transmission media surround us. For example:

- When two people converse, **air** acts as the medium carrying sound waves.
- In postal services, vehicles and aircraft serve as mediums to carry letters.
- In telecommunications, the medium could be copper wire, fiber optics, or even free space, depending on the technology in use.

Digital communication systems convert information into **signals** — either electrical currents or light pulses — which then propagate through the chosen medium. These signals, which are essentially electromagnetic energy, may vary in frequency and wavelength depending on the application.

In modern networking, **guided media** such as fiber optics are often preferred for their high bandwidth and reliability, while **unguided media** like radio waves are essential for mobile and flexible communications.

CLASSES OF TRANSMISSION MEDIA

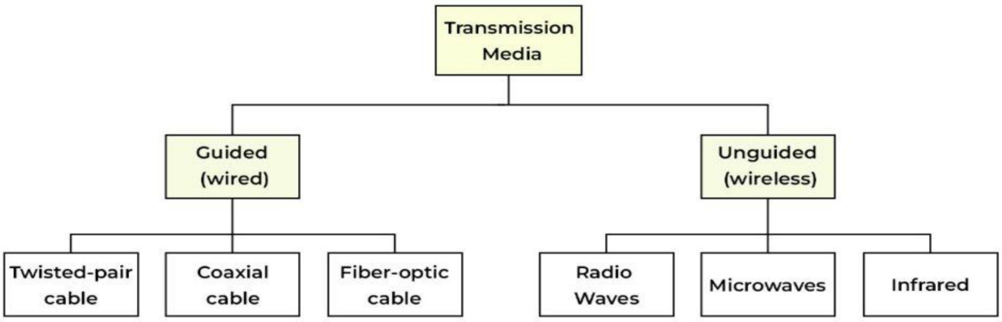

Fig 2.1 Classes of Transmission Media

2.1 TRADITIONAL WIRED MEDIA (WIRED)

Guided media refers to communication channels that use a physical path to direct signals from one device to another. The signal is contained and guided by the boundaries of the medium. Common examples include **twisted-pair cables**, **coaxial cables**, and **fiber-optic cables**.

2.1.1 TWISTED-PAIR CABLE

A twisted pair consists of two conductors (normally copper), each with its own plastic insulation, twisted together, as shown in Figure 2.2.

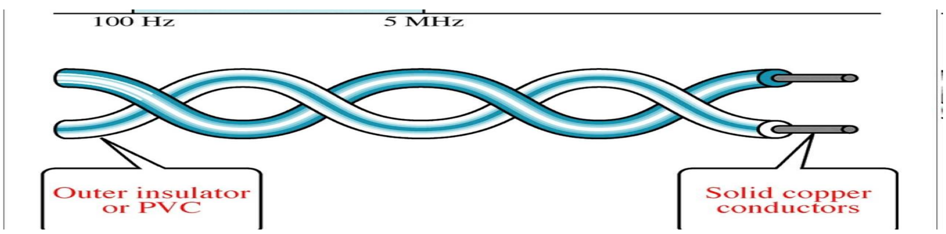

FIG 2.2 Twisted Pair Cable

A **twisted-pair cable** is made of two insulated copper wires wound around each other. One wire carries the signal, while the other serves as a reference or ground. The twisting pattern helps reduce **electrical interference** and **crosstalk** from nearby cables. When wires are twisted, any noise affecting one wire is likely to also affect the other in the same way, which allows the receiver to cancel out unwanted signals.

Advantages:

- Low cost and easy installation
- Widely used in telephone lines and local area networks (LANs)

Limitations:

- Limited bandwidth and distance compared to coaxial or fiber optics
- More susceptible to interference over long distances

2.1.2 COAXIAL CABLE

A **coaxial cable** consists of a central copper conductor surrounded by an insulating layer, a metallic shield (often made of braided copper or foil), and an outer plastic cover. The metallic shield protects the signal from external interference, enabling coaxial cables to carry higher-frequency signals than twisted pairs.

Coaxial cables are identified by **Radio Government (RG) ratings**, which specify their construction and performance characteristics, such as inner conductor thickness, insulation type, and shielding.

Advantages:

- Better noise resistance than twisted pair
- Supports higher bandwidth for data and video transmission

Limitations:

- Thicker and less flexible than twisted-pair cables
- More expensive and harder to install in tight spaces

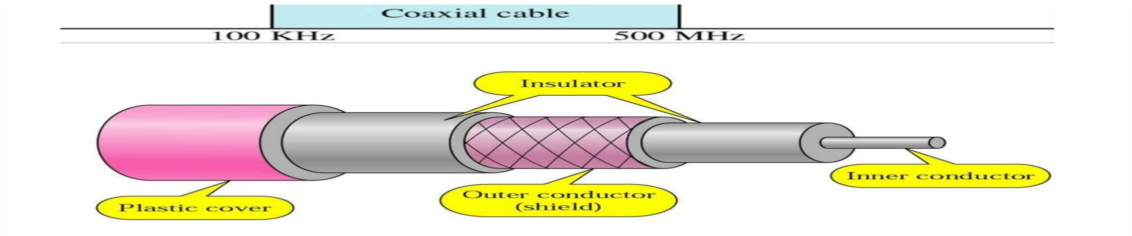

Fig 2.3 Coaxial Cable

2.1.3 FIBER-OPTIC CABLE

A **fiber-optic cable** uses strands of glass or plastic to transmit data in the form of **light pulses**. It relies on the principle of **total internal reflection**, where light traveling through the cable's core is reflected back into the core by the surrounding cladding.

Fiber-optic cables can carry data over very long distances at extremely high speeds without significant signal loss. They are immune to electromagnetic interference, making them ideal for high-performance networks.

Advantages:

- Extremely high bandwidth
- Very low signal attenuation over long distances
- Resistant to electrical noise and interference

Limitations:

- Higher installation cost compared to copper cables
- Requires specialized equipment for splicing and maintenance

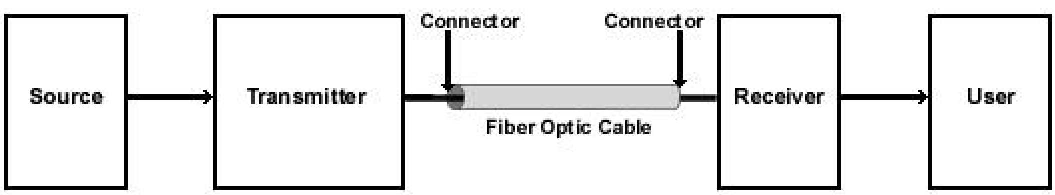

Fig 2.4 Fibre-Optic Cable

2.2. TRADITIONAL UNGUIDED MEDIA (WIRELESS)

Unguided media carry electromagnetic waves **without a physical conductor**. Instead of traveling through cables, the signals are transmitted through **open space**, such as air or vacuum. This method is commonly known as **wireless communication**.

In wireless systems, signals are broadcast into the environment, allowing any properly equipped receiver within range to pick them up. Depending on the frequency and application, wireless signals may travel through:

- **Ground propagation** – signals follow the curvature of the Earth
- **Sky propagation** – signals bounce off the ionosphere
- **Line-of-sight propagation** – direct travel between antennas without obstruction

The portion of the electromagnetic spectrum used for wireless communication typically ranges from **3 kHz to 900 THz**, covering various technologies.

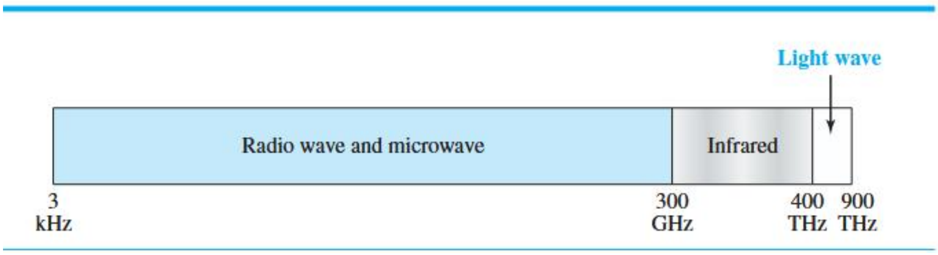

Fig 2.5 Electromagnetic Spectrum of Wireless Communication

2.2.1 RADIO WAVES

Radio waves occupy the **3 kHz to 1 GHz** frequency range. They are **omnidirectional**, meaning they spread in all directions from the transmitting antenna. This allows receivers to pick up the signal without precise alignment, but also makes them prone to interference from other sources using the same frequency.

Because they can travel long distances and penetrate buildings, radio waves are widely used for **broadcasting** (e.g., AM/FM radio) and for indoor communications.

Drawback: Their wide coverage can make it hard to limit signal access to a specific area.

2.2.2 MICRO WAVES

Microwaves operate between **1 GHz and 300 GHz** and are **unidirectional** — they travel in a straight, narrow beam between the transmitter and receiver. For reliable transmission, both antennas must be aligned.

Key characteristics:

- **Line-of-sight requirement:** Tall towers or repeaters are often used to overcome obstacles and Earth's curvature.
- **Poor wall penetration:** Microwaves cannot pass through solid structures easily, making them less effective indoors.
- **High capacity:** Their wide frequency range supports high-speed data transmission and multiple channels.

Applications include satellite links, point-to-point communication, and wireless backhaul connections.

2.2.3 INFRARED WAVES

Infrared waves have frequencies between **300 GHz and 400 THz** and are typically used for **short-range communication** such as remote controls, wireless keyboards/mice, and some point-to-point links. Since infrared cannot pass through walls, it avoids interference between rooms but is unsuitable for long-distance communication .It also performs poorly outdoors because sunlight contains infrared radiation, which can interfere with the signal.

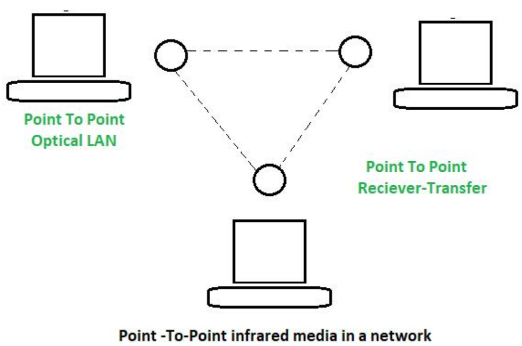

Fig 2.6 Infrared Waves

3.MODERN TRANSMISSION MEDIA

Modern transmission media represent the latest advancements in data transfer technologies, combining **speed, efficiency, and flexibility** to meet the demands of today's interconnected world. These innovations have transformed communication systems, enabling everything from **real-time video conferencing** to **global IoT ecosystems**.

Modern media fall into two main categories: **Modern Wired (Guided)** and **Modern Wireless (Unguided)**.

3.1 Modern Wired (Guided) Media

Modern wired technologies focus on increasing bandwidth, improving signal quality, and supporting long-distance communication without significant degradation.

Key Technologies in Modern Wired Media:

1. **Dense Wavelength Division Multiplexing (DWDM)**
    - Uses multiple wavelengths of light in a single fiber to massively increase data capacity.
    - Supports transmission speeds exceeding Tbps (terabits per second).
    - Widely used in telecom backbones and undersea cables.
2. **Gigabit Passive Optical Network (GPON)**
    - A **fiber-to-the-premises (FTTP)** technology delivering speeds up to **2.4 Gbps downstream** and **1.2 Gbps upstream**.
    - Uses time-division multiplexing to serve multiple users through one fiber.
    - Popular for **home fiber internet (FTTH)** services.
3. **Category 7 & Category 8 Ethernet Cables**
    - Enhanced twisted-pair cables supporting speeds from **10 Gbps up to 40 Gbps**.
    - Shielded to reduce interference, making them ideal for **data centers**.
4. **Hybrid Fiber-Coaxial (HFC) Networks**
    - Combines fiber optics for long-distance backbone with coaxial cables for last-mile delivery.
    - Commonly used by **cable internet providers**.

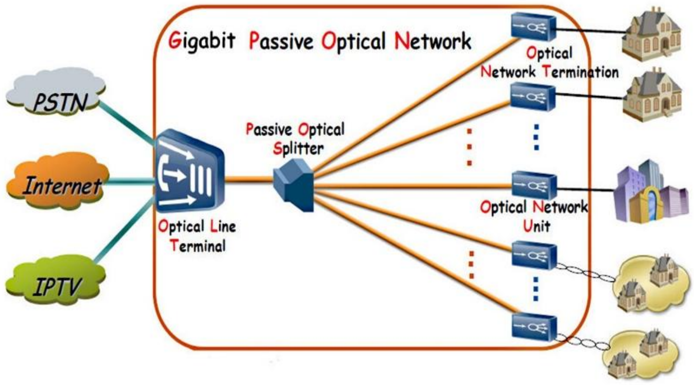

Fig 2.7 GPON

3.2 Modern Wireless (Unguided) Media

Modern wireless communication has evolved to deliver **fiber-like speeds** without the constraints of physical cables. Mobility, scalability, and rapid deployment make it indispensable in today's world.

Key Technologies in Modern Wireless Media:

1. **5G Cellular Networks**
   - Offers speeds of **1–10 Gbps**, ultra-low latency (~1 ms), and massive device connectivity.
   - Enables applications like **autonomous vehicles**, **smart cities**, and **AR/VR streaming**.
2. **Wi-Fi 6 and Wi-Fi 6E**
   - Supports higher speeds, improved capacity, and better performance in crowded environments.
   - Wi-Fi 6E adds access to the **6 GHz spectrum** for faster, interference-free connections.
3. **Li-Fi (Light Fidelity)**
   - Uses visible, infrared, or ultraviolet light to transmit data.
   - Capable of speeds exceeding **200 Gbps** in lab conditions.
   - Ideal for **secure indoor communication** since light does not pass through walls.
4. **Low Earth Orbit (LEO) Satellite Internet**

- Uses a constellation of satellites orbiting at 500–2,000 km above Earth.
    - Provides global coverage, including remote and rural areas.
    - Examples: **Starlink**, **OneWeb**.

5. **Massive MIMO (Multiple Input Multiple Output)**
    - Uses large numbers of antennas at base stations to improve capacity and coverage in 4G/5G networks.

3.3 Trends in Modern Transmission Media

- **Hybrid Networks:** Many organizations combine **fiber backbones** with **wireless access points** for best performance and flexibility.
- **Edge Computing Integration:** Data processing closer to the source reduces latency for time-sensitive applications.
- **Green Networking:** New materials and designs aim to lower the energy consumption of transmission systems.
- **Future 6G Research:** Expected to achieve **100 times the speed of 5G** with AI-driven network optimization.

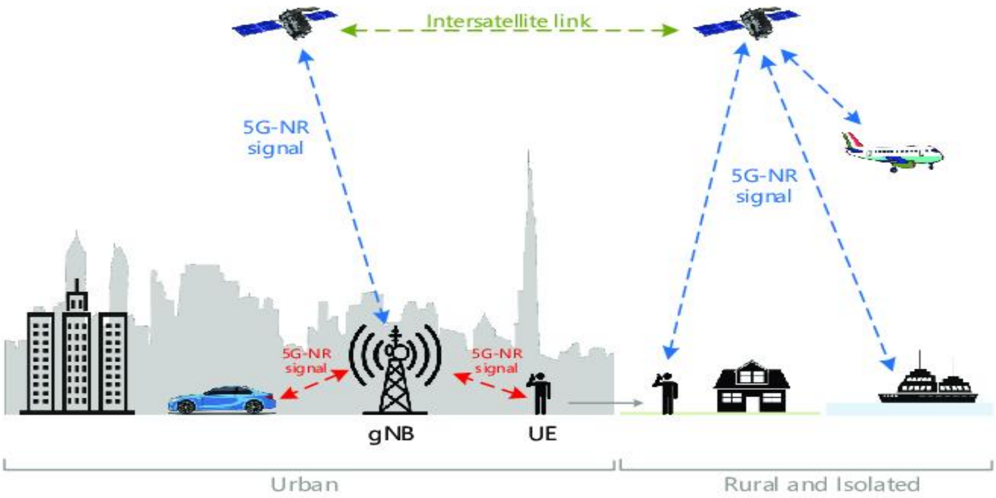

Fig 2.8 Intersatellite link

4.COMPARISONS BETWEEN WIRED AND WIRELESS COMMUNICATION

Both wired and wireless transmission media are vital in modern networking, but each has unique characteristics that make it suitable for specific applications. This section compares the two based on installation, mobility, cost, security, performance, and more.

4.1 COMPARITIVE TABLE

S/N	Characteristics	Wired Networks	Wireless Networks
1	Installation	Difficult to moderate	Easy installation (neat, no untidy cables)
2	Visibility Node to Node on same network	All nodes can hear each other	Many nodes cannot hear all other nodes
3	User connectivity	Limited to physically connected computers	Possible beyond physical cabling
4	Mobility	Limited to connected	Outstanding (connect anytime,

		computers	anywhere)
5	Hubs and switches	Required for connections	Not required
6	Security	Good (software like firewalls)	Weak (signals can be intercepted,but encryption can improve security)
7	Standards	802.3	802.11a, 802.11b, 802.11g
8	Quality of Service	Better	Poor (delays and longer setup times)
9	Connection Setup Time	Less	More
10	Types	LAN, MAN, WAN	SatelliteNetworks: • Wi-Fi (802.11) Networks • Hyperlan2 Networks • Bluetooth Networks • Infrared Networks

4.2 Analysis of Key Factors

1.Installation Complexity

Wired networks demand careful planning for cable layout, drilling, and the installation of wall outlets or cable trays. For example, setting up a wired LAN in a multi-story office can take days or even weeks, depending on building structure. Wireless networks, in contrast, can be deployed in hours by simply installing wireless routers and configuring devices.

2.Mobility and Flexibility

Wired connections restrict devices to fixed points, which is ideal for stationary workstations but inconvenient for mobile devices like laptops or tablets. Wireless networks allow employees to move freely between meeting rooms, workstations, and break areas without losing connectivity — a huge advantage in modern collaborative workplaces.

3.Cost Considerations

While wired setups often involve higher initial installation costs (especially with fiber optic cables), they may require less maintenance over time. Wireless solutions have lower upfront costs but may require frequent upgrades to keep up with evolving standards (e.g., upgrading from Wi-Fi 5 to Wi-Fi 6).

4.Security

Wired networks are inherently more secure because physical access to the cable is necessary to intercept data. However, they are not immune to insider threats or physical tampering. Wireless networks require robust encryption methods (like WPA3) and authentication mechanisms to protect against unauthorized access.

5.Performance and Reliability

Wired connections generally deliver higher and more stable speeds, making them ideal for tasks like video editing, gaming, or data center operations. Wireless performance can vary depending on signal range, interference from walls or other devices, and network congestion.

4.3 Choosing Between Wired and Wireless

The decision depends on the intended use case:

- **Wired** is preferable for **data centers, security systems, and critical business networks** requiring maximum speed and reliability.
- **Wireless** is better suited for **environments requiring mobility**, such as universities, hospitals, and large public areas.
- Many organizations adopt a **hybrid approach**, using wired connections for core infrastructure and wireless for end-user convenienc

5. CONCLUSION

Transmission media play a critical role in the effectiveness of communication systems. Guided media, such as twisted pair cable, coaxial cable, and fiber optic cable, are commonly used for transmitting signals in LANs and WANs, while unguided media, such as radio waves, microwaves, and infrared waves, are used for wireless communication. Each type of transmission medium has its own advantages and disadvantages, and several factors must be considered when selecting a medium, including bandwidth, distance, interference, cost, and reliability.

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