CSN-341
Computer Networks
Physical Layer Assignment

Group-6

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Explain the recent methods and technologies used at the physical layer, including various media at different levels and signaling for data transmission.

The physical layer is responsible for the transmission of raw data bits over a communication medium. It defines the hardware connections, electrical impulses, light pulses, or radio waves that carry the data, and establishes how bits are transmitted from one device to another. Depending on the size and scope of the network, different transmission methods and media are employed. These can be broadly categorized by network size as follows:

1. **Personal Area Network (PAN):**
   - Media: Bluetooth, Infrared, USB cables.
   - Signaling: Short-range wireless (Bluetooth), low power consumption, USB uses differential signaling to minimize noise.
2. **Local Area Network (LAN):**
   - Media: Ethernet cables (copper, twisted pair), Wi-Fi, Fiber optic.
   - Signaling: Digital signaling, modulation techniques like OFDM (Wi-Fi), NRZ (Ethernet), and signaling over fiber-optic with light pulses.
3. **Metropolitan Area Network (MAN):**
   - Media: Fiber optics, Microwave, Cable (coaxial).
   - Signaling: Fiber-based signaling using Dense Wavelength Division Multiplexing (DWDM) for high data rates, microwaves for wireless.
4. **Wide Area Network (WAN):**
   - Media: Fiber optics, Satellite, Copper lines (for legacy systems).
   - Signaling: SONET/SDH for fiber-based WANs, satellite communication uses modulation techniques such as QPSK.

5. **Intercontinental Networks:**
    - Media: Undersea fiber-optic cables, Satellite.
    - Signaling: Advanced modulation methods like DWDM over fiber, satellite systems using phase shift keying (PSK).

We will explore LAN in detail to learn more about the new technologies in this field.

A local area network (LAN) is a collection of devices connected together in one physical location, such as a building, office, or home. A LAN can be small or large, ranging from a home network with one user to an enterprise network with thousands of users and devices in an office or school.

We aim to improve data transmission speeds and reliability of signals by incorporating new physical layer technologies in LANs. Here are a few physical layer technologies related to the same:

Network devices in LAN

1. **Switches**: These connect many devices to wire the whole devices group, such as computers and printers, and forward data among them. The modern LANs widely employed use Ethernet switches.
2. **Routers**: They help connect the LAN to other networks, such as the internet. Therefore, routers determine what data should be routed between the LAN and the WANs.
3. **Access Points (APs)**: Access points are the building blocks of WLANs; they connect wireless devices, be they laptops or smartphones, with the wired LAN.
4. **Firewalls**: They could either be hardware or software-based, and the purpose of firewalls is to control incoming and outgoing traffic on the network.
5. **Network Interface Cards (NICs)**: These are installed in devices (computers, printers) to allow communication over the network, either by Ethernet or Wi-Fi.

Media in LANs

1. **Copper Twisted pair cables:** The Unshielded Twisted Pair(UTP) cables are the standard used for ethernet communications.UTP cables are twisted in helical fashion like a strand of a DNA.They are quite inexpennsive and don't cause much problems when bent.
   The UTP cables versions are named as category or Cat.Higher categories like Cat 6A, Cat 7, and Cat 8 are used for Gigabit and even 40 Gigabit Ethernet.
   Signaling: Ethernet over twisted pair uses baseband signaling, often with non-return to zero (NRZ) encoding. More advanced systems use PAM-5 signaling (Pulse Amplitude Modulation with 5 levels).

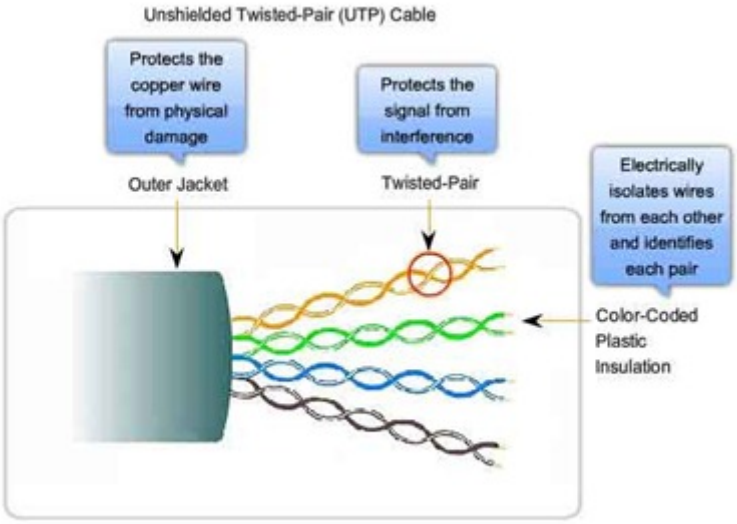

Figure 1: UTP cable

2. **Fiber Optic Cables:** These use the principle of Total Internal Reflection of light to send signals to long distances.
   The FO cable is made up of pure glass which is extremely transparent, one can see through that glass to about 40-kilometer distance as it offers almost no resistance to the passing light. The FO cables carry light pulse and the existence of a light pulse indicates 1 and absence indicates 0.
   The electrical signals are to be converted to the light pulses at the sender and converted back to electrical pulses at the receiver. The device called photodiode is used at the receiver to convert a light pulse into an electric current.
   Single-mode fiber is used for long-distance and multi-mode fiber is used for shorter, high-speed connections (up to 100 Gbps).In a single mode as only one ray can run through this cable at any given point of time.
   Signaling: LAN fiber networks use laser-based signaling and Dense Wavelength Division Multiplexing (DWDM) to send multiple signals simultaneously over different wavelengths of light.

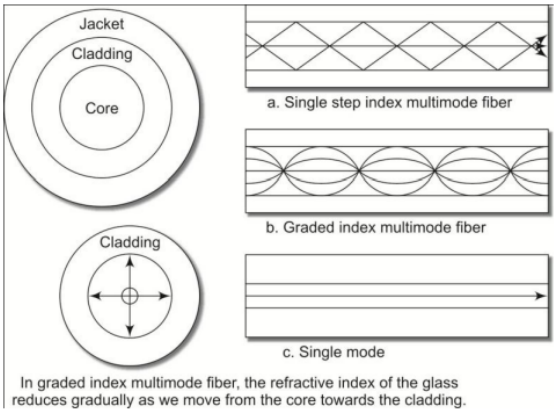

Figure 2: Single and multimode fibers

3. **Wi-Fi (Wireless LAN):** Wi-Fi is a wireless networking technology that uses radio waves to provide wireless high-speed Internet access.
   It does not need specific addressing and is easy to eavesdrop. The receiver can be anywhere in the vicinity and the message would reach it even if it is mobile. The downside is that the spectrum is shared and thus wireless physical layer is always short of bandwidth.
   It follows standards like IEEE 802.11 standards, with recent updates like Wi-Fi 6 (802.11ax) and upcoming Wi-Fi 7.
   Signaling: Orthogonal Frequency Division Multiplexing (OFDM) is the primary signaling method used in modern Wi-Fi, which divides the channel into multiple smaller sub-channels, each carrying a part of the data.

Signaling techniques:

1. **Ethernet signaling:** Ethernet signaling has evolved over time, from 10BASE-T to 100BASE-TX to 1000BASE-T and now 10GBASE-T. 10BASE-T uses Manchester encoding, while 100BASE-TX and higher speeds use 4B/5B or 8B/10B encoding schemes to ensure DC balance and error detection.
   Higher-speed systems, like 10GBASE-T, use PAM-16 modulation, which increases the number of levels of signal amplitude to represent more bits per signal transition, thus increasing throughput.
2. **Wifi-signaling(OFDM):** OFDM breaks the signal into smaller sub-signals that are sent simultaneously over different frequencies. This improves resistance to interference and allows higher throughput.
   QAM (Quadrature Amplitude Modulation) is often combined with OFDM, allowing multiple bits to be transmitted per symbol by modulating both the amplitude and the phase of the carrier signal.

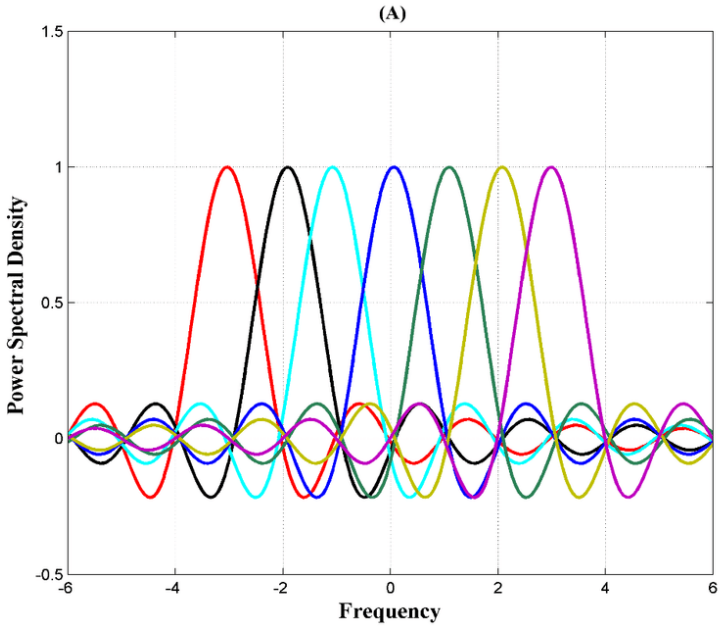

Figure 3: OFDM signaling

3. **Fiber Optic Signaling** LANs using fiber optics typically employ DWDM or CWDM (Coarse Wavelength Division Multiplexing). These techniques send different signals over multiple wavelengths of light, increasing the amount of data transmitted over a single fiber strand.
   Laser-based signaling ensures high-speed data transmission, with advanced error correction methods like forward error correction (FEC) to ensure integrity over long distances.

Recent Developments in LAN signaling

1. **High Speed Ethernet:** 2.5G, 5G, and 10G Ethernet: As demands for higher data rates increase, new Ethernet standards are being adopted, which require improved media (like Cat 6A/7/8 cables) and sophisticated signaling techniques like PAM-16 or PAM-5.
2. **Wi-Fi 6 and Wi-Fi 7:** Wi-Fi 6 (802.11ax) has brought substantial improvements in terms of efficiency, signal strength, and range. It uses MU-MIMO (multi-user, multiple-input, multiple-output) to handle more devices simultaneously and OFDMA (Orthogonal Frequency Division Multiple Access) to increase efficiency in crowded networks.
   Wi-Fi 7 (802.11be) is expected to offer even greater speeds and efficiency through 320 MHz channels and 16 spatial streams, significantly boosting wireless LAN performance.
3. **Power over Ethernet (PoE):** Newer Ethernet standards like IEEE 802.3bt allow the transmission of both data and power over Ethernet cables, supporting devices like IP cameras and VoIP phones without needing a separate power source. PoE is evolving to support higher power levels, which is essential for IoT devices in LAN environments.