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**1. Introduction to WANs**

**WAN Standards**

* **Evolution of WANs:** WAN technology has evolved from telegraph systems to modern data networks, incorporating standards from previous technologies like radio and telephony.
* **Standard Organizations:**
  + **TIA/EIA:** Telecommunications Industry Association and Electronic Industries Alliance.
  + **ISO:** International Organization for Standardization.
  + **IEEE:** Institute of Electrical and Electronics Engineers.

**WANs in the OSI Model**

* **Focus on Layers 1 and 2:** WAN standards typically emphasize the Physical (Layer 1) and Data Link (Layer 2) layers of the OSI model.
  + **Layer 1 Protocols:** Handle the transmission of bits over a WAN, including standards like SDH, SONET, and DWDM.
  + **Layer 2 Protocols:** Define how data is encapsulated into frames for transmission, including protocols like Ethernet WAN, MPLS, and legacy technologies like Frame Relay and ATM.

**2. WAN Terminology and Devices**

**Common WAN Terminology**

* **DTE (Data Terminal Equipment):** Device that connects the subscriber's LAN to the WAN (e.g., router).
* **DCE (Data Communications Equipment):** Device that connects the subscriber to the WAN service provider (e.g., modem).
* **CPE (Customer Premises Equipment):** Equipment at the subscriber's location, which may include both DTE and DCE devices.
* **POP (Point-of-Presence):** The connection point between the subscriber and the service provider's network.
* **Demarcation Point:** The physical point separating the subscriber's network from the service provider's network.
* **Local Loop:** The actual physical connection (copper or fiber) from the CPE to the service provider's central office (CO).
* **Central Office (CO):** The service provider’s local facility connecting the CPE to the provider's network.
* **Toll Network and Backbone:** High-capacity network infrastructure within the WAN provider's network, connecting different regions or countries.

**WAN Devices**

* **Voiceband Modem:** Legacy device for converting digital signals to analog voice frequencies.
* **DSL and Cable Modems:** High-speed broadband modems connecting to WAN via telephone or coaxial cables.
* **CSU/DSU:** Device for connecting digital lines to LANs, ensuring signal integrity and converting data formats.
* **Optical Converter:** Device for converting signals between fiber-optic and copper media.
* **Wireless Router/Access Point:** Device for wireless WAN connectivity, often using cellular networks.
* **WAN Core Devices:** High-speed routers and multilayer switches in the WAN backbone.

**3. WAN Communication Methods**

**Serial Communication**

* **Serial vs. Parallel:** Serial communication sends bits sequentially over a single channel, unlike parallel communication, which sends multiple bits simultaneously.
* **WAN Suitability:** Serial communication is preferred for WANs due to its ability to handle long distances without synchronization issues.

**Circuit-Switched Communication**

* **Dedicated Circuits:** Establishes a dedicated path between endpoints before communication begins (e.g., landline telephony).
* **Inefficiencies:** Circuit switching uses a fixed channel for the entire communication session, potentially leading to underutilized capacity.
* **Examples:** PSTN and ISDN are common circuit-switched WAN technologies.

**Packet-Switched Communication**

* **Shared Network:** Data is divided into packets that are routed over a shared network, allowing multiple communications on the same channel.
* **Cost-Effective:** More flexible and economical than circuit switching, suitable for modern data communication.
* **Examples:** Ethernet WAN, MPLS, and legacy technologies like Frame Relay and ATM.

**4. Optical Fiber WAN Technologies**

**SDH, SONET, and DWDM**

* **SDH and SONET:**
  + **SDH (Synchronous Digital Hierarchy):** Global standard for fiber-optic data transmission.
  + **SONET (Synchronous Optical Networking):** North American equivalent of SDH.
  + **Redundant Fiber Paths:** Both standards use ring topologies with redundant paths for reliable data transmission.
* **DWDM (Dense Wavelength Division Multiplexing):**
  + **Increased Capacity:** DWDM increases data transmission capacity by sending multiple data streams simultaneously over different wavelengths of light.