Reviewer:

Long-Distance Digital Connection Technologies (Chapter 08)

1. Digital Telephony

- **Analog communication:** Method od sending signals with the help of using continuous signals (voice).
- **Problem:** Long-distance analog signals lose quality due to distortion.
- **Solution: Digitization** of audio (Pulse Code Modulation) → clearer, more efficient transmission.
- **Repeaters** amplify and extend signals but can introduce distortion in analog systems.

2. Synchronous Communication & Leased Lines

- **Leased lines:** are full-time connections between two specified locations
- **Used for:** Voice, data, or video transfer.
- **Modern systems:** It ensures digitized voice data is carefully sent and received at a specific rate

3. Digital Circuits & DSU/CSU

- **Digital circuits:** Use binary (1s and 0s).
- **DSU/CSU (Data Service Unit / Channel Service Unit):** refers to a device that terminates the digital line, ensuring proper connection and signal integrity.
    - DSU: Handles transmission & buffering.
    - CSU: Manages connection and line control.
- Connects internal digital equipment to external carrier networks (e.g., T1, DDS).

4. T-Series Digital Lines:

- T-Carrier Lines are a historical telecommunications standard for digital data transmission, such as T1 and T3 line
- **T-Carrier system**: Digital voice/data lines.
    - **T1** = can carry 24 simultaneous voice channels. 1.544 Mbps (24 channels at 64 Kbps each).
    - **T2** = 4 × T1 lines.
    - **T3** = 28 × T1 lines (≈ 44.736 Mbps).
- **Use:** Common for business data and voice transmission.
- **Cost (2025):**
    - T1: $200–$1,000/month.
    - T3: $500–$1,500/month.

5. Intermediate Capacity – Inverse Multiplexing (IMUX)

- Inverse Multiplexing (IMUX) is a communications networking technique which uses an inverse multiplexer to connect the termination of several digital lines
- **Multiplexing:** Combine multiple lower-speed lines into one faster link.
- **Inverse Multiplexing:** Splits data across multiple lines → recombines it at the destination.
- **Often uses DSU/CSU devices.**

6. Highest Capacity Circuits – STS & SONET

- **STS (Synchronous Transport Signal):**
    - digital signal format that transmits multiple voice or data channels.
    - Standard digital signal format for large-scale telecom networks.
    - Uses a common clock → precise synchronization.
- **SONET (Synchronous Optical Network):** protocol for transmitting multiple digital data streams over optical fiber using lasers
    - Fiber-based standard for high-speed data transfer.
    - Uses **OC (Optical Carrier)** levels:
        - **OC-1:** 51.84 Mbps
        - **OC-3:** 155.52 Mbps

- "C" (e.g., OC-3C) → combined continuous bandwidth.

7. Local Subscriber Loop ("Last Mile")

- physical pair of copper wires or fiber that Connects customer to telephone central office.
- **Problem:** Old copper lines limit speed (voice-only design).
- **Solutions:** DSL, cable broadband, or fiber-to-home connections.

8. ISDN (Integrated Services Digital Network)

- a circuit-switched telephone network system designed to carry digital voice
- Early digital upgrade for phone lines.
- **Channels:** 2 × 64 Kbps (B channels) + 1 × 16 Kbps (D channel).
- Allowed simultaneous voice, data, video.
- Obsolete today (slow, costly vs. broadband).

9. DSL (Digital Subscriber Line) **Technologies**

Type	**Description**	**Speed / Notes**
ADSL Asymmetric Digital Subscriber Line Technology	Ad: Finds frequencies with a high signal-to-noise ratio on the line. Dis: No guaranteed data rate	Down: 32 Kbps–6.4 Mbps
SDSL	Symmetric speeds (equal up/down)	Reliable for businesses
HDSL (High-Rate Digital Subscriber Line):	Provides speed of T1/DS1 – 1.544 Mbps in both directions.	Requires 2 twisted pairs
HDSL2	Like HDSL, but uses 1 pair	Supports bridge taps
VDSL Very-High Bit Rate DSL	Very high speed (up to 52 Mbps)	Fiber to neighborhood required

10. Cable Modem Technology

- Uses **coaxial cable** (same as TV) → high bandwidth, low interference.
- Uses **frequency-division** and **time-division multiplexing**.
- **Limitations:**
  - Shared bandwidth (slower with more users).
  - Security concerns → need firewalls.

11. Hybrid Fiber-Coax (HFC)

- Combines **fiber (main backbone, high capacity, long distance)** + **coax (last mile, short distance from neighborhood node to homes)**.
- High-speed service but requires expensive setup.

12. Alternatives

- **Fiber to the Curb (FTTC):** Fiber close to home, coax/twisted pair for final connection.
- **WiMAX:** Wireless broadband, up to 155 Mbps, ~30-mile range.
- **Satellite Internet:** Uses geostationary satellites; wide coverage, high latency.

WAN Technologies and Routing (CHAP09)

1. Types of Networks

- **LAN (Local Area Network):** connects devices within a limited area, like an office, building, or even a home
- **MAN (Metropolitan Area Network):** a computer network that interconnects users in a geographic region of the size of a metropolitan area.

- **WAN (Wide Area Network):** a telecommunications network that extends over a large geographic area.

2. Packet Switching

- **Concept:** Data divided into packets, forwarded across network.
- **Store-and-Forward:** Packets stored in switch memory, then forwarded.
- **Packet Switches:** Small computers with network interfaces, memory, and routing programs.
- **Physical Addressing:** Each packet has a header (source + destination address).

3. Forwarding & Routing

- **Next-Hop Forwarding:** Switch forwards packet to next switch toward destination.
- **Source Independence:** Routing decision depends only on destination, not source.
- **Hierarchical Addressing:** Routing tables group entries to simplify lookups.
- **Routing Process:**
    - **Static Routing:** Manually configured, no automatic updates.
    - **Dynamic Routing:** Updates automatically, adapts to failures.

4. Routing Protocols

- **RIP (Routing Information Protocol):** Chooses path with fewest hops (small networks).
- **OSPF (Open Shortest Path First):** Uses shortest path algorithms (large networks).
- **BGP (Border Gateway Protocol):** Connects different networks (used in the Internet).

5. WAN Architecture

- **Interior Switch:** Only connects switches.
- **Exterior Switch:** Connects switches and computers.
- **Capacity Expansion:** Add more switches or faster links.
- **Modeling WANs:** Represented as graphs (nodes = switches, edges = links).

6. WAN Technologies (Examples)

- **ARPANET:** First packet-switched WAN (1960s, U.S. DoD).
- **X.25:** Early WAN standard (1970s), reliable but slow.
- **Frame Relay:** Used in 1990s, faster than X.25.
- **ATM (Asynchronous Transfer Mode):** Supports voice, video, data with fixed-size cells.
- **SMDS (Switched Multi-megabit Data Service):** Connectionless WAN service, flexible speeds.

7. Key Takeaways

- WANs = large-scale networks connecting LANs and MANs.
- Use **packet switching, routing tables, and algorithms** for data delivery.
- **Graph algorithms** (e.g., Dijkstra's) help compute shortest paths.
- WAN tech evolution: **ARPANET → X.25 → Frame Relay → ATM → SMDS → Internet.**

Chapter 11: Internetworking

1. Motivation

- Many **LAN** and **WAN** technologies exist.
- Real-world organizations use multiple network types.
- Need: A system to connect **different technologies → Internetworking**.

2. Universal Service

- **Telephone model:** Any phone can reach another → valuable.
- Computers become more useful when they achieve the same.
- Requires connecting networks of **different technologies**.

3. Internetworking

- **Definition:** interconnects multiple networks of dissimilar technologies
- Uses:
  - **Hardware** (e.g., routers).
  - **Software** (on each connected computer).
- Result: An **internetwork (internet)**.

4. Routers

- Device that links 2+ networks.
- Has **interfaces** for different network types.
- Functions:
  - Forwards packets between networks.
  - Transforms packets if needed to meet standards.
- Can have **multiple interfaces**.
- Organizations often use **several routers** for:
  - Higher capacity.
  - Reliability (rerouting if one fails).

5. Internet Architecture

- composed of multiple networks interconnected by routers

5. Virtual Network

- Internetworking software creates **one seamless virtual network** from many.
- Provides:
  - **Universal addressing system.**
  - **Universal connectivity.**
- Hides details of physical networks from users & applications.

6. TCP/IP Protocol Suite

- Most widely used set of internetworking protocols.
- First major suite for internetworking (original concept: **catenet**).
- Developed by **ARPA**, later supported by **NSF**.
- Became dominant because:
  - Works across platforms & vendors.
  - Independent of specific hardware.
- Today: Supports **millions of devices worldwide**.

7. Other Internetworking Protocols

- IPX, VINES, AppleTalk.
- Replaced by **TCP/IP** as the global standard.

8. TCP/IP Layering (5 Layers)

1. **Application Layer 5**
   - (ISO 6 & 7)
   - Handles communication between applications.
2. **Transport Layer 4**
   - (ISO 4)
   - Provides Reliable data delivery.
3. **Internet Layer 3**
   - Defines packet formats, routing, forwarding rules.
4. **Network/Data-Link Layer 2**
   - Defines packet formats and rules for forwarding across networks
5. **Physical/Hardware Layer 1**
   - (ISO 1)
   - Defines basic networking hardware.

9. Hosts, Routers, and Protocol Layers

- **Host:** Any computer attached to the internet running applications.
- Hosts can be small PCs or supercomputers.
- **Routers:** Handle physical interconnection & packet forwarding.

- **TCP/IP:** Allows **any pair of hosts** to communicate directly.

Key Takeaways

- Internetworking = connecting **different networks** into one seamless system.
- **Routers** are essential for interconnection, transformation, and reliability.
- **TCP/IP** is the dominant protocol suite, replacing older ones.
- The **TCP/IP model (5 layers)** is simpler than the OSI model.
- Provides **universal connectivity** and a **virtual network** for users.